

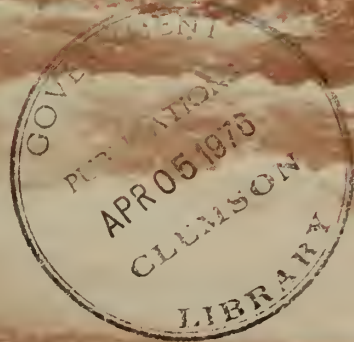
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Sport Fishery and Wildlife Research 1973-74

Clemson University



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UNITED STATES DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service



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Fish and Wildlife Service

Divisions of Research

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Cover Photo
Bears fishing in McNeil Creek, Alaska
(by Dick Chace)

SPORT FISHERY AND WILDLIFE RESEARCH 1973-74

**Activities in the Divisions of Research for the Calendar
Year 1973 and the First Half of 1974**

**Edited by
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and
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FOREWORD

Public awareness of our natural environment and its misuse continues to grow. In the fish and wildlife sector, concern is increasing for endangered species and for nongame wildlife. If wild populations of many forms of fish and wildlife are to be maintained in the face of changing and dwindling habitat resulting from human activity, more must be known about the animals' biology, ecology, and behavior. This is the function of sport fishery and wildlife research.

The purpose of this publication is to relate some of the activities and accomplishments of sport fishery and wildlife research in the U.S. Fish and Wildlife Service. The report covers the period of 1 January 1973 through 30 June 1974, and changes the reporting period for this and future annual reports from calendar to fiscal year.

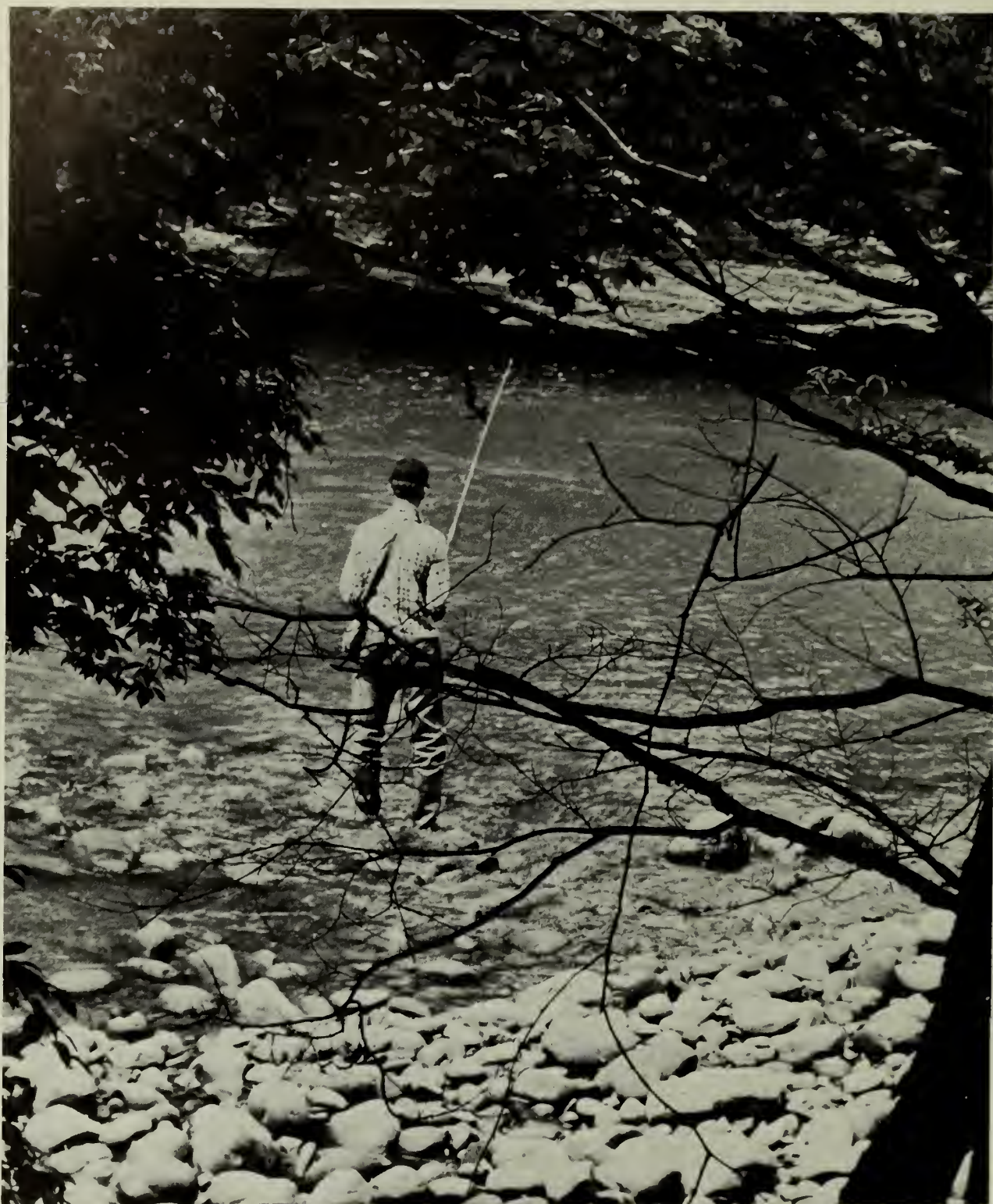
Change in program objectives, more refined definitions of National needs, and greater emphasis on establishing priority research for problems needing early solutions were some of the changes that occurred in sport fishery research. Among these changes was increased research on the genetics of heritability traits of several species of fish to determine strains useful to particular management purposes. More attention was given to environmental effects on fishery resources, and a new impetus was directed toward the management and restoration of coastal anadromous fishes, including Atlantic and Pacific salmons, striped bass, and shad.

In wildlife research, the Marine Mammal Protection Act of 1972 created new research responsibilities for four species: polar bear, walrus, sea otter, and manatee. A significant expansion in the study of predators and predator-prey relationships, especially of the coyote, became imperative as a result of the executive order banning the use on public lands of all chemical toxicants for killing predatory mammals and birds, and all chemical toxicants which cause secondary hazards to other wildlife.

Progress in the Service's research program depends upon the cooperation and support of many friends outside the Divisions of Research. We thank those who made this work possible. We hope the reader will find something of interest and value in this report.

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Trout fishing in West Virginia. Fishing is the end product of sport fishery research and management. Research is providing not only the knowledge required for effective stocking of trout waters, but also information for management of natural populations of fish in streams, lakes, and reservoirs. (Photo by Ben Schley)

SPORT FISHERY AND WILDLIFE RESEARCH

During 1973 and the first half of 1974, the Divisions of Sport Fishery and Wildlife Research continued to serve as the factfinding arm of the U.S. Fish and Wildlife Service. Facts about species of fish and wildlife, the environment required for their existence, and the effects of management practices on them help the U.S. Fish and Wildlife Service and other governmental agencies in their responsibilities for conserving and managing the Nation's fish and wildlife for social, economic, aesthetic, and scientific benefits. In fulfilling the Service's research responsibilities, the Divisions cooperate with agencies of the Departments of Interior, Agriculture, Defense, and Health, Education, and Welfare; the Atomic Energy Commission; the Agency for International Development; the Environmental Protection Agency; and various State agencies and private organizations. Completed research is communicated by talks and lectures, processed reports, and articles in popular and technical publications. The final section of this report provides a list of publications.

During the period of this report, research was carried out at 19 major facilities, 61 satellite field stations, and 45 Cooperative Research Units under the following programs: Animal Damage Control, Biological Monitoring, Coastal and Anadromous Fish, Endangered Species, Great Lakes Fisheries, Inland Fishery Management, Environmental Impact Assessment, Migratory Birds, Mammals and Nonmigratory Birds, Reservoirs and Related Waters, and Cooperative Units. This realignment of programs resulted from the adoption by the Fish and

Wildlife Service of a new management system, Management by Objective (MBO). MBO permits the application of total agency resources toward the attainment of specifically detailed objectives. It impacts primarily upon the research activities of the Service by encouraging careful priority assessment of on-going research programs and by redirecting effort toward information needs related to carefully established program goals.

In July 1974, the Divisions of Fishery Research and Wildlife Research were reorganized into four Divisions of Research: Cooperative Research, Cultural Methods, Population Ecology, and Population Regulation. These four divisions were established to associate similar research activities more closely by function than by classification. For example, environmental pollution research is similar regardless of whether the organism studied is a fish or a bird. Because the reorganization is in effect at this writing, the directory in the Appendix will represent the current organization.

The planning, coordination, and administration of the research programs continue to be centralized in the Washington, D.C. offices. Fiscal, personnel, and property management and a variety of supporting services are provided for the research facilities and the units by the six Regional Offices of the Service. By the end of F.Y. 1974 the Divisions of Research had 570 professional employees and 196 nonprofessional employees. The budget included approximately \$18,790,000 of appropriated funds and \$1,650,000 of other funds.

ANIMAL DAMAGE CONTROL

Denver Wildlife Research Center

Distribution of sheep in the West.—Much of the Fish and Wildlife Service's predator damage research is focused on gathering data to clarify the coyote-sheep controversy. Since predator damage problems are closely related to the distribution and density of livestock, a neces-

sary part of this research was a survey to determine sheep populations in western United States.

Data from several sources indicate that numbers of stock sheep in the 17 westernmost States have declined steadily from 21.5 million in 1959 to 12.5 million in 1972. This 1972 figure represented about 80% of the total 15.7 million sheep

population in the 48 contiguous States. Texas that year led in numbers of stock sheep (3.1 million), followed by Wyoming (1.60 million), California (1.01 million), South Dakota (0.99 million), Montana (0.95 million), Utah (0.89 million), New Mexico (0.71 million), and Colorado (0.67 million). Sheep densities calculated for each of the 1,059 counties surveyed revealed that Wyoming had the most sheep per square mile of total land area (16.4), followed by South Dakota (13.2), Texas (11.9), Utah (10.8), Idaho (7.6), and California, Colorado, and Montana together (6.5). Seven counties had more than 100 sheep per square mile; six of these were in the Edwards Plateau of central Texas, and the seventh was in south-central Idaho.

In 1972, sheep-grazing allotments on Bureau of Land Management lands were so intermingled with cattle-grazing allotments that acreages could not be accurately separated, but 1.6 million sheep (plus lambs under 6 months of age) were permitted to graze on portions of 68 of the 97 national forests. They grazed for

an average of 2.45 months of the year on 15.3 million acres, or nearly 11% of the 142.6 million total national forest acreage. Cattle and sheep combined grazed on about 36% of the total acreage.

1973 predator survey in western United States.—Data from the 1973 predator survey were compiled and released as a progress report in May 1974. This is the second year the fall survey has been conducted by the Division of Wildlife Services, with the assistance of the Divisions of Research and Refuges, and State and university cooperators.

A total of 354 survey lines was run in the 17 western States during September. Each line consisted of 50 scent stations, spaced at 0.3-mile intervals along ranch or secondary roads; each station was a 3-foot circle of sifted earth or sand with a perforated capsule filled with a standard attractant in the center. Weather permitting, survey lines were run for 5 consecutive days, and animal visits, based on tracks, were recorded on standard forms.



A coyote at a scent station. Survey lines consisting of 50 of these stations at 0.3-mile intervals are being run for 5 days each fall to estimate the relative densities of coyotes throughout the West. (Photo by F. R. Henderson)

The information was forwarded to Oregon State University where, under contractual agreement, the data were coded and punched onto cards, relative indices of abundance were calculated, and results were summarized on computer printouts. The 1972 and 1973 coyote indices were then compared by a chi-square test to determine if significant statewide differences were evident. Five States (South Dakota, Nebraska, Colorado, New Mexico, and Oklahoma) showed significant increases in relative coyote densities in 1973; three States (Oregon, Idaho, and Utah) showed significant decreases. The Idaho indices were significantly different at the 0.10 level of probability, Colorado at the 0.05 level, and all other States at the 0.01 level.

Sheep losses to predators in shed-lambing operations.—The first year's data have been tabulated in a study to determine total sheep mortality, and that portion due to predation, at three Idaho ranches where ewes are brought in to lamb in sheds. Mortality among 8,750 ewes during the 2-1/2-month lambing period at the three ranches was 1% (86). Mortality among 12,836 lambs during the same period was 6.5% (832), but predation is rarely a problem in and around shed areas and only 11 of the 832 lambs were killed by predators. Ewes are on range-lands the other 9-1/2 months each year, but the lambs are sold after 4 months of range grazing. On the range, ewe losses totaled 5.7% (509) and lamb losses during their relatively short stay on the range totaled 5.2% (623). Verified predation was 1.4% (141) for ewes and 1.1% (141) for lambs; maximum possible predation (including unaccounted-for losses) was 3.4% for ewes and 4.4% for lambs. Most lamb losses, both verified and unverified, occurred between 1 April, when they were turned out on the range, and 1 June, when they were moved to forest lands. Coyotes were responsible for 93% of the verified predation losses.

Pen tests of coyote repellents.—The potential use of chemical repellents, applied to sheep to reduce coyote predation, depends in part on the coyote's ability to "learn" that contact with the repellents results in an unpleasant experience. A preliminary study showed that penned coyotes could be quickly conditioned (by electric shock) to avoid live black rabbits and feed only on white rabbits, and that they remained conditioned for 3 to 9 months without reinforce-



A ruler-like measuring device with superimposed 58-day-old coyote fetus. The ruler was designed for aging coyote fetuses and determining breeding dates in the field (actual size of ruler, 2 × 8 inches). (Photo by Brad E. Johns)

ment. Therefore, screening tests were initiated with candidate chemical repellents applied on live rabbits. For each compound, four coyotes, all preconditioned to kill and eat white rabbits within the 2-hour daily test period, were exposed on alternate days to treated and control white rabbits for a 10-day period. Differences in the rate of killing between treated and control rabbits provided a measure of efficacy. Two of six compounds tested in this manner showed potential. After sheep collars containing a repellent reservoir were fabricated, a field test of one of these, DRC-6264, was begun in North Dakota in June 1973.

Reproductive inhibitor tested on Norway rats.—On the day they were paired with males, female Norway rats were dosed with a single 10-mg/kg oral dose of an estrogenic reproductive inhibitor (DRC-4805). The females did not litter until 105 days after receiving the chemical. When young rats suckled on mothers that had been treated with a single 1-mg/kg oral dose the day after littering, only 1 of 16 males and 0 of 16 females proved to be fertile at maturity. Additional efficacy data are being obtained by testing the chemical under colony conditions. This reproductive inhibitor offers considerable promise in an area of rat population management that has been often discussed but, to date, has not produced a practical control agent.

New transmitter for grizzly bears.—A wildlife telemetry transmitter designed for tracking grizzly bears incorporates several new features. In addition to providing the normal radio pulses for tracking, this transmitter monitors activity by emitting extra pulses when the



This 4-pound transmitter for grizzly bears functions as a normal, fast-pulsed radio-tracking unit while the animal is active but switches to a slow pulse during hibernation to conserve the batteries. (Photo by A. Lawrence Kolz)

animal moves. If all movement stops, the transmitter switches to a slow pulse after an hour, and this signals mortality during periods when bears should be active. During hibernation, the slow pulse conserves the batteries.

Other features include a resealable molded plastic case (3/8-inch wall thickness), a replaceable power pack with four lithium batteries, a magnetic turn-on switch, an encapsulated antenna, and a circuit design that allows the transmitter to operate at reduced efficiency even if three of the four batteries should fail. The unit weighs only 4 pounds total and has a predicted operating life of 2 years.

Progress in control of forest-animal damage.—In recent years there has been a need to update traditional forest-animal damage control methods because of restrictions on pesticide use, increasing demands for timber, and changing forest management practices aimed at more efficient timber production and increased wildlife, recreation, and aesthetic benefits. To meet this need, greater emphasis is being placed on developing biological and/or ecological methods to reduce wildlife damage to conifers in Oregon and Washington.

In seed protection studies, mestranol, a non-toxic, rapidly biodegradable estrogen widely used on Douglas-fir seed, has shown promise as a repellent to deer mice, the species causing the most losses in forest reseedling programs. In cage tests, consumption of 2% mestranol-treated Douglas-fir seed by deer mice was reduced 76% in 5 days and 90 to 99% thereafter for 6 months. Consumption of the same seed by juncos (the most common avian seed eater) was reduced 41% in 10 days. In field tests, the 2% mestranol treatment was about as effective as the standard 0.5% endrin-treated seed, resulting in up to six times more 1st-year germinants in almost all study areas than untreated seed. In both laboratory and field tests with deer mice, there was no evidence of gonadopause or no measurable differences in fecundity or postnatal mortality between test and control animals. Gonad regression occurred in some laboratory-tested male juncos but not in females or in field-collected juncos from test areas in Washington. Effects on the forest ecosystem are still being studied, but all data to date indicate that mestranol is biologically and environmentally safe and a leading candidate for replacing endrin as a Douglas-fir seed protectant.

For seedling restocking programs, small cylindrical plastic-net seedling protectors appear to be one good answer to the problem of wildlife feeding injury. Several years of testing various designs and installations were recently concluded, resulting in a photodegradable material, that lasts 3 to 4 years, does not significantly hamper seedling height growth and provides good protection of Douglas-fir seedlings from hares, rabbits, deer, and elk. Cost of material is about 10¢ per tree for 3–4 years protection, long enough for good establishment in most Douglas-fir plantations. The cylinders protect seedlings better than any available chemical repellent and the protection results in average seedling height gains of over 130 feet per acre per year. The protector is being widely adopted by forest managers in the Pacific Northwest and is being evaluated for both conifers and hardwood species in other parts of the United States.

Two other methods of protecting conifer seedlings, both using native plants, have shown promise in preliminary studies. One is a deer-

repellent formulation of rhizome tissue from wild ginger. This material has shown excellent deer repellent qualities in individual preference and group exposure pen tests, and application to growing Douglas-fir foliage also protected seedlings from deer in Oregon and Washington study areas. Toxicological tests to date indicate that the wild ginger formulation is relatively nontoxic, and the feasibility of using wild gin-



A plastic net protects seedlings from injury by wildlife. The material is photodegradable and lasts for 3 to 4 years. (Photo by Dan L. Campbell)

ger extracts as water soluble, systemic repellents is being investigated. The second method involves establishment of forbs preferred by wildlife and noncompetitive with Douglas-fir. Preliminary studies in Washington suggest that stands of three such forbs—catsear, fleabane, and phacelia—could be rapidly established on newly burned and scarified plantations. Such habitat modification may provide a practical method for reducing damage to Douglas-fir seedlings while improving wildlife habitat, an approach too often overlooked in the past.

Rat-resistant varieties of sugarcane.—Optimum yields in Hawaiian sugarcane are dependent on the continual development of new, high-yielding, and disease-resistant varieties of cane, and a major portion of the industry's research program is directed to this end. However, at present the program cannot actively select for rat resistance because the specific traits of sugarcane associated with rat damage are unknown. In an attempt to provide some of this information, 6 physical and 16 chemical characteristics of three varieties of cane on the island of Hawaii and three varieties on Kauai were measured and related to rat damage.

In the plots on Hawaii, damage was inversely related to rind hardness, stalk diameter, and nitrogen content and directly related to calcium content. In the Kauai plots, damage was inversely related to internode length only. Damage was not related to measures of sugar content on either island. These inconsistent results between Hawaii and Kauai suggest that the 22 parameters selected for measurement do not encompass the cause of variety preferences or that preferences are not based on a single parameter and interactions are confounding the results.

Aquatic hazards of zinc phosphide.—Most sugarcane fields in the Hamakua district of Hawaii are 300 feet or less from uncultivated lands. These wildlands, primarily small gulches, provide excellent rat harborage and serve as population reservoirs from cane harvest until suitable habitat develops in maturing cane. Currently, the zinc phosphide-oat groat bait used in canefields is not federally registered to control rats in Hawaii's noncrop areas. To meet one requirement for noncrop registration, the acute hazards of the bait to freshwater shrimp, Tahitian prawns, and gobies were assessed.



Gulches interspersed among sugarcane fields function as habitat reservoirs for three species of rats that damage sugarcane in Hawaii. (Photo by Glenn A. Hood)

Static water bait bioassays were completed on three size classes of both shrimp and prawns. At least three treatment levels (different numbers of 1.88% zinc phosphide oat kernels) and equivalent control levels (untreated kernels) were each free-fed for 7 days to five individuals per size class. Gobies were given bait by gavage, since they would not eat oats.

Some shrimp died after feeding on as few as eight treated kernels; prawns, after as few as two. In both species, the smallest individuals were the most susceptible. Of the gobies force-fed three treated kernels, 20% died 5 hours after treatment. The remaining gobies regurgitated the bait within 4 hours, compared with 12 hours for those force-fed untreated kernels.

These results indicate that contamination of gulch streams with zinc phosphide-treated bait represents a potential primary hazard to shrimp and prawns. Acute hazards to gobies are not likely because of their complete rejection of the bait.

Cooperation with the IBP-Grassland Biome Study.—The Denver Wildlife Research Center is participating in the International Biological Program, Grassland Biome Study by conducting studies of small mammal populations on the San Joaquin Experimental Range in California. In 1973, almost 26,000 trap-nights were accumulated in studies of small rodents on grazed and ungrazed pastures in California oak-annual rangeland. During this 1st year of

the study, some rodent species often associated with open grasslands—San Joaquin pocket mouse, California pocket mouse, and Heermann's kangaroo rat—were seldom trapped. On the other hand, the pinyon mouse, brush mouse, and dusky-footed woodrat, species associated with rocks and brush, were prevalent. The deer mouse was seldom encountered. The mean density of small rodents was 1.6 per acre on the grazed area and 1.1 per acre on the ungrazed area. The California ground squirrel population was estimated to be 3.4 per acre.

A random survey of burrowing and mound building activity revealed that pocket gophers and other burrowing rodents removed approximately 1.6% of the surface area from production on the grazed site and 0.4% of the surface area on the ungrazed site. These detailed studies of the ecology of grassland rodents will not only contribute to the Grassland Biome Study, but will assist the Fish and Wildlife Service in assessing the total impact of rodents on the range ecosystem and in evaluating the need for rodent control and the potential effects of such control.

Ground squirrels and cattle compete for forage.—Every year, millions of acres of grassland are treated with toxicants to suppress populations of California ground squirrels, traditionally considered a serious competitor with domestic livestock for forage. However, a study of the foods and feeding habits of California ground squirrels on the San Joaquin Experimental Range, where squirrels have not been poisoned for 12 years, indicates that this species should have little impact on vegetation production on modestly grazed native range in the California annual type.

This study shows that California ground squirrels feed almost entirely on forage from January to April, the green forage season. However, the average daily adult forage requirement is only 1.2 ounces for males, 0.9 ounce for non-reproductive females, 1.1 ounces for pregnant females, and 1.8 ounces for lactating females. Young are not fully weaned until early May, so they are of no importance as consumers during the green forage season. Further, there is little or no weight gain in adults during the season, so the only energy requirement is for maintenance and reproduction. Since the average number of adult ground squirrels in the



Streams in Hawaii were electro-shocked to inventory aquatic fauna and assess hazards to nontarget species of controlling rats with zinc phosphide baits in the adjacent sugarcane fields. (Photo by Larry F. Pank)

experimental pastures is 3.4 per acre (1.6 males and 1.8 females per acre), this population requires about 28.9 pounds of forage per acre from January through April to provide maintenance energy for the adults, intrauterine development of fetuses, and milk for the young. The long-term average peak forage biomass on the area is 1604.9 pounds per acre; thus, the resident California ground squirrels require only 1.8% of the forage produced.

Although ground squirrels apparently have little effect on forage production on moderately grazed pastures, this might not be true in pastures where production is low and squirrel populations are high. For instance, in a pasture with an average forage production of 501.1 pounds and a population of 10 squirrels per acre, the squirrels' requirement of 85.0 pounds of forage during the green forage season would be approximately 17% of available production, enough to significantly compete with livestock.

Sustained-release implants for controlling fertility in white-tailed deer.—Initial tests have shown that permeable plastic rods filled with



In simulated warehouse tests, a biologist evaluates ultrasonic devices claimed to repel rodents. (Photo by G. Keith LaVoie)

synthetic progestin, a crystalline steroid hormone (DRC-6246), and implanted beneath the skin of the ear are effective in preventing pregnancy in captive white-tailed does. In this sustained-release system, the hormone slowly diffuses through the plastic and is carried to its site of action, the anterior pituitary, where it probably interferes with the release of the gonadotrophic hormone, LH. A reduction in LH interferes with ovulation. Examination of the ovaries after treatment showed the formulation of large Graffian follicles that had become either cystic or luteinized, preventing normal ovulation.

After 90 days posttreatment, the implants were extracted and assayed for the remaining hormone. They had lost an average of 12 mg, or about 130 μg per day. At this diffusion rate, an implant should be effective about 1,100 days (3 years), provided fibrotic encapsulation does not occur.

Although such implants require handling each target animal and may not last the reproductive life of a doe, the very simple implanting procedure and the lack of bait acceptance and environmental contamination problems make implants an attractive possibility for managing wild ungulate populations.

Ultrasound fails as a rat deterrent.—The use of ultrasound (frequencies above the range of human hearing) to deter or remove rodents from buildings has been of interest to biologists

for several years. Published reports of the aversive effects of ultrasound on white and wild Norway rats in laboratory experiments gave promise of a new nonchemical tool for the control of noxious rodents. Several types of ultrasound devices are currently on the market, each with a manufacturer's claim of effectiveness. After laboratory tests of five models to determine their physical properties under controlled conditions, two were selected for field testing on the basis of physical properties that had shown promise in laboratory experiments by other investigators.

One device had a wide frequency range, producing a broad continuous noise pattern; the second had an intermittent narrow frequency output, approaching a pure tone. The devices were installed in a warehouse containing a population of Norway rats, and normal rat feeding activity was recorded during a 3-week monitoring period. The devices were then turned on for a 3-week period and the difference in feeding activity was determined. Under test conditions, the device with the broad frequency pattern failed to alter the activity of the rats. The second device, with a narrow frequency output, caused an initial decrease in feeding, but the rats soon became accustomed to it and resumed normal activity. The volume of the sound emitted seemed to have little effect on the rats, since they frequently fed within a few inches of the operating devices. Ultrasound, at least that produced by the two devices tested, apparently does not afford long-term protection from rat depredation.

Vampire bat research continues in Latin America.—On 11 December 1973, a closing ceremony was held in Palo Alto, Mexico, for the highly successful cooperative vampire bat project. This project, a cooperative effort between the Mexican government and personnel of the Wildlife Research Center at Denver under the sponsorship of the U.S. Agency for International Development (AID), was started in June 1968 to solve the age-old problem of protecting livestock from vampire bat attacks. Rabies transmitted by these bats is one of the major problems confronting the Latin American cattle industry. Starting with only the most basic information, in less than 6 years, the team developed two safe and effective methods for protecting cattle from vampire bats.

The official inauguration of a national campaign against vampire bats in Nicaragua was celebrated on 23 April 1974. Although other Latin American countries are sponsoring limited vampire bat control efforts, Nicaragua is the first to underwrite a full-scale national campaign. The Nicaraguan government has appropriated \$570,000 for a 5-year effort (\$170,000 for the 1st year and \$100,000 for each year thereafter). Twenty-two technicians assigned to the campaign were trained by Denver Center personnel and are working in teams of two men to a vehicle. They began in the states of Boaco and Granada where losses are the most severe.

In addition to the campaign, a joint study evaluating vampire attacks on beef animals was begun by Denver biologists, together with personnel from Texas A & M University and the Nicaraguan Ministry of Agriculture. Weight gain, hematology, and blood parasites are being investigated to determine how controlling vampire bat populations will affect the economics of raising beef cattle.

Insectivorous bats susceptible to diphenadione.—A method recently developed to protect Latin American cattle from vampire bat attack involves capturing the bats near corrals, treating them topically with diphenadione, and releasing them to carry the anticoagulant back to contaminate their roosting colony. Since vampire bats do not mix with other species, this technique is highly selective if properly used. However, to determine what would happen if insectivorous bats were treated by mistake, the acute oral toxicity of diphenadione was determined for two representative species—the big brown bat and the little brown bat.

The LD₅₀ (the amount of a toxicant killing 50% of the animals treated) with 95% confidence limits was found to be 2.8 (1.1–7.5) mg/kg for big brown bats and 2.8 (0.2–45.3) mg/kg for little brown bats. Females appeared to be more susceptible than males in both species. Two of five male and four of five female big brown bats died; one of four male and five of six female little brown bats died. Only females died at low doses.

These results indicate that diphenadione would be highly toxic to nontarget bats if they became contaminated, and they point out the need to make accurate field identification before

applying topical treatments for vampire bat control.

Relative acceptance by Philippine ricefield rats of bait from two types of containers.—In the Philippines, where rat damage is a severe problem in ricefields, anticoagulant baits are usually exposed in baiting “huts”—wooden trays 1 or 2 feet across with a sheltering metal roof. Preliminary research by personnel of the Rodent Research Center (sponsored by the U.S. Agency for International Development and partially staffed by personnel from the Wildlife Research Center, Denver) showed poor bait consumption at these huts. On the theory that social interactions were limiting feeding, the team tested a different kind of baiting station—a collection of discarded quart oil cans, each stapled to a small plywood square for stability.

Consumption of untreated rice by rats from oil-can stations placed at four points in 1- to 4-week-old rice average 1,074 g per night by the 15th–17th nights of exposure. Consumption at four baiting huts placed alternately at 50-m intervals between the can stations averaged 313 g during the same period. At each of five tallies during the 17 days of exposure, bait loss was greater from cans than from the huts. As consumption increased, additional cans were added at each can station and more rice to each hut. In 13 of 20 visits, all the bait was consumed from the cans, while the huts were emptied only seven times.

Monitoring with a closed-circuit infrared television unit showed striking differences in feeding activity at the two types of containers. In 5 hours of monitoring the huts with the highest loss on the 10th and 16th nights of exposure, no more than two rats were seen feeding simultaneously. In 2-1/2 hours of monitoring the oil-can site with the highest loss on the 17th night of exposure, from 6 to 15 rats were feeding at all times. Feeding at the huts was always interrupted whenever another animal approached. At the can stations, activity at one can usually did not disturb feeding at other cans nearby.

These results indicate that the effectiveness of baiting programs using anticoagulants could be greatly improved by exposing the bait at stations with many small bait containers, which allow many more animals to feed than do single large baiting huts.



Two tree-climbing rodents, roof rats and tree squirrels, cause heavy losses to coconut crops in Colombia. Rats gnaw into the end of the nut near the stem (top); squirrels penetrate at the side (bottom). (Photos by Donald J. Elias)

Rodent damage in coconut regions of Colombia.—Rodents cause heavy losses to coconut palm crops in almost all countries where they are grown. In Colombia, preliminary surveys have shown average damage levels varying from 32% on the Pacific Coast to 49% on the Atlantic Coast to a staggering 77% on San Andreas Island. The rodents primarily responsible for this damage are roof rats, which gnaw into maturing coconuts on the ends near the stem, and tree squirrels which gnaw at the side. Damage varies from superficial scarring to complete penetration of the husk and soft shell. Moderately scarred nuts will remain on the tree until maturity, but once the inner shell is penetrated the nut falls off.

On San Andreas Island, a preliminary field trial was conducted with a commercially avail-

able anticoagulant rodenticide called Ramik, containing 0.005% diphenadione in a grain base. About 250 palms were treated by placing a sealed plastic bag containing approximately 75 g of bait in the crown of the tree. The results indicated that diphenadione bait was highly effective in controlling rodent damage in coconuts. The pretreatment survey had shown damage of over 77%; the posttreatment survey revealed no damage. Since rodent damage is costing the coconut industry over \$1,000,000 a year, wide-scale application of this simple control method could have a tremendous impact on the economy of the island.

Nonlethal electrical barrier for rat control.—

In the Philippines, nearly every crop grown is subject to damage by ricefield rats. A prototype model of an electrical barrier has been developed for controlling ricefield rat damage to high-value crops such as corn, soybeans, and other vegetables. Nonlethal shock levels were chosen to insure safety to humans and to lessen the labor involved in removing electrocuted rats from the barrier. Preliminary semifield evaluations using different barrier designs were conducted to develop the most effective barrier for the lowest construction costs. Barrier height, angle, and electrode spacing were tested for effects on rat avoidance and protection of rice grain. The resulting prototype barrier, which laboratory tests indicated is up to 95% effective in repelling rats, is 18 inches high, with a 45° slant on the top portion, and contains two electrode wires. The shock source is a commercially available livestock electric fence shocker modified to deliver three to five shock pulses per second. If the barrier is properly maintained, one shock source should protect enclosures of up to 350 acres. Field evaluation of the prototype barrier is planned on 2.5-acre study areas in the Philippines in the fall of 1974.

Rice variety preference.—A variety of rice commonly grown in Southeast Asia (FK-178A) has been shown to be consistently preferred by ricefield rats in semifield and laboratory preference tests. Consumption was almost 350% greater for FK-178A than for two other Philippine varieties (IR-20 and C-4) and 300% greater than for the native Milagrosa variety. Thus the damage potential for FK-178A in the field may be greater than for other varieties, especially after the rice is harvested.



This albino Polynesian rat, caught near Hilo, Hawaii, is the first albino taken in 10,200 captures representing 125,000 trap-nights. (Photo by Larry F. Pank)

Gas chromatographic records of the volatile flavor constituents in these four Filipino varieties and a domestic variety (California Brown) revealed several chemical differences. Although generally the same volatile compounds are present in the five varieties, their relative proportions are different. Correlation analyses between rat preference and biochemical data should indicate the flavor constituents that are most attractive to rats. This information will be used to develop a synthetic rice-flavor bait additive for improved field control of ricefield rats.

New analytical methods developed for chemical control agents.—New methods have been developed for the isolation, identification, and estimation of three toxicants used as damage control agents—compound 1080 (sodium fluoroacetate), 4-aminopyridine (the avian frightening agent), and zinc phosphide. All are gas-liquid chromatographic (GLC) methods

that allow detection at very low levels (0.1–0.2 ppm for 1080, 0.01 ppm for 4-aminopyridine and zinc phosphide).

The 1080 method involves homogenizing the sample with water, filtration or centrifugation, precipitation of water-soluble proteins, a liquid-liquid extraction, recovery of fluoroacetic acid (and other carboxy acids of biological origin) from aqueous solution with a basic ion exchange resin, recovery of the acid from the resin, and a microdistillation followed by formation of the ethyl ester. The ester is detected and estimated by GLC with hydrogen flame-ionization detection. A sample containing as little as 1 ppm of sodium fluoroacetate will yield enough ethyl fluoroacetate to permit unequivocal identification by gas-chromatographic mass-spectrometry (GC-MS).

In support of registration for 4-aminopyridine in sunflower fields, a method was developed



This new double-compartment trap has proved very effective in capturing territorial males for banding and color-marking in Wyoming and Colorado. This territorial male is about to enter the trap to attack the decoy, an adult male redwing in the lower compartment. (Photo by Olin E. Bray)

to measure residues in sunflower plants and their oily seeds. After thorough grinding of the sample, 4-aminopyridine is extracted with a water-immiscible solvent, back-partitioned into water, recovered from aqueous solution with a weakly acidic cation exchange resin, recovered from the resin, and detected and estimated by GLC with flame-ionization detection. A sample containing 0.05 ppm of 4-aminopyridine is concentrated enough for positive identification by GC-MS.

In support of tests to assess environmental contamination resulting from rodenticide baiting with zinc phosphide, a method was developed to measure residues in range vegetation. The sample is acidified in a sealed flask to hydrolyze zinc phosphide to phosphine gas, and the gas is then sampled from the headspace and analyzed by GLC with flame-photometric detection.

New movement information from color-marked male redwings on their territories.—Banding of over 45,000 red-winged blackbirds in the past 12 years has provided much infor-

mation on the movements of the population that winters in Colorado. However, recoveries during the breeding season have been disappointingly low—only three from Wyoming. In addition, only one redwing has been recovered from banding 1,498 nestlings in Wyoming.

To determine if this population could be used for a planned field chemosterilant program, more information was needed to link specific redwing breeding marshes in Wyoming and Colorado to specific wintering areas in Colorado and more southerly States. It was obvious that the answers could not be easily provided by more winter or nestling banding, so biologists turned to banding and color-tagging male redwings on their breeding territories in Wyoming and Colorado and then searching for the tagged birds at various winter roosts.

In 1972 and 1973, using a new trapping technique developed for this purpose, researchers captured about 600 male redwings on their breeding territories in north-central Wyoming, and about 60 in north-central Colorado, and marked them with 3-inch-long plastic leg streamers color-coded for location. In searches during January 1973 and 1974, 5 of the Wyoming-tagged birds were found about 450 miles south among a half million redwings wintering in the Arkansas Valley near Las Animas, Colo., and 19 were discovered among 200,000 wintering in the South Platte and St. Vrain River valleys north of Denver, Colo. There were also 13 sightings of Colorado-tagged birds in the latter area and 1 sighting in the Panhandle of Texas. These sightings provided the first information to tie local breeding populations in Wyoming and Colorado with specific wintering populations.

Fifty-five marked birds, a surprisingly large number, were trapped in Wyoming in 1973. Of these, 48 were males marked in the same marshes in 1972, 5 were nestlings banded in Wyoming in 1971, and 2 were males banded in the South Platte Valley of Colorado in January 1971 and January 1973. About 28% of the colored tags were known to have been retained for at least 1 year. The high percentage of recaptures demonstrates the tendency of redwings to return annually to the same marsh to breed.

The new trapping technique that permits marking of territorial males appears to have great potential for future movement studies.

With this technique, about 12 man-weeks of effort produced many times more information on Wyoming breeding birds than gained from all previous winter banding in Colorado and nestling banding in Wyoming.

Bird damage to wine grapes surveyed in California.—Early in 1973, a statewide questionnaire survey was conducted to determine bird damage to raisin, table, and wine grapes in California. Results showed damage to grapes to be widespread but probably most severe in the wine varieties grown in the coastal counties of central California. To more accurately assess losses to wine grapes in this area and to help set bird damage research priorities, a field survey of bird damage in nine of these counties was conducted before the 1973 grape harvest with the help of County Agricultural Commissioners. The results showed that birds, mostly house finches and starlings, damaged or destroyed an estimated 1.99% of the crop in the nine counties, or from 1,547 to 5,219 tons of grapes worth at least \$750,000.

Winter distribution of blackbirds and starlings in the Central Flyway.—Since 1960, over 132,000 blackbirds and starlings have been banded in the Central Flyway States as part of a research program to reduce crop damage. Banding and color-marking have been the primary means of gathering data on breeding and wintering areas and migratory routes.

The widely divergent wintering areas of several species that are closely associated in late summer is one of the more interesting revelations of band recovery analyses. For example, five species commonly share communal roosts at Sand Lake National Wildlife Refuge in South Dakota during the late summer molt and early autumn migration. By early winter, most of the yellow-headed blackbirds and brown-headed cowbirds have moved to south-central Mexico, about 1,800 miles southwest of Sand Lake. Red-winged blackbirds and common grackles generally winter 1,000 miles south-southeastward in eastern Texas, Louisiana, and adjacent States. Starlings winter some 500 miles to the southwest in eastern Colorado. This fanning out into diverse areas in winter probably has survival value related to such factors as food, roosting cover, and climate.

Feeding ecology of blackbirds in California.—To better understand the complex patterns



Five blackbird species that roost together in large flocks during late summer at Sand Lake National Wildlife Refuge, South Dakota, migrate to different regions for the winter. (Illustration by Willis C. Royall, Jr.)

of blackbird damage to rice in the Sacramento Valley, Calif., the food habits of the area's five blackbird species were studied during 1969–73. Analysis of the stomach and esophageal contents of 875 birds taken from this area revealed that amounts of commonly available food items eaten varied substantially among the five species. Rice, for example, was a larger portion of the annual diet of red-winged, tricolored, and yellow-headed blackbirds (44%, 38%, 38%, respectively) than of brown-headed cowbirds (25%) and Brewer's blackbirds (15%). Insects comprised a larger portion of the annual food of Brewer's (24%) and tricolors (18%) than of redwings (9%), yellowheads (9%), and cowbirds (3%). Variations in amounts taken were also noted for oats, wildmillet, other cultivated grains, weed and grass seeds, plant matter, ground-dwelling beetles, other beetles, and grit. In addition to these interspecific feeding differences, intraspecific differences between sex and age classes of tricolors and redwings were detected. Males of both species ate more rice, cultivated grain, and plant matter than females of the same species, and juvenile tricolors ate more weed and grass seeds and fewer insects than adults. Such interspecific and intraspecific feeding differences complicate

the problem of selectively controlling those individuals most responsible for damage. However, chemical repellent crop sprays, such as methiocarb, appear to protect rice from all five blackbird species and all ages and sexes.

Patuxent Wildlife Research Center

High redwing female to male ratio in Ohio.—An average of at least 4.4 female red-winged blackbirds per nesting territory was found during the 1973 breeding season in northern Ohio. This female:male ratio exceeds the usual 2 to 3 females per male recorded in past studies on redwings, and is attributed, in part, to the interchange of females between territories. The study was conducted between 30 April and 6 August in a 16-acre area of old-field habitat found to contain 17 territorial males and at least 68 female redwings.

The 68 females, which were trapped on nests and tagged with colored leg-streamers, built at least 85 active nests in the study area; and be-

tween nesting attempts at least 8 of the 68 females switched territories within the study area. The presence of 20 other active nests in the 16-acre area indicated that additional females probably were present during the 14-week study period.

Knowledge of breeding sex ratios is important for use in developing population dynamics models and in predicting the response of populations to potential control measures. It is of special importance in polygamous species such as the crop-depredating red-winged blackbird. If future studies substantiate these preliminary findings, our understanding of redwing productivity will be greatly clarified.

Selection of nesting habitat by redwings.—Habitat selection by male red-winged blackbirds was investigated intensively in a heterogeneous wetland area near Ann Arbor, Mich., during the breeding season. The 13-acre study plot was typical of Michigan ephemeral marshes, with 1 foot or more of water in early



A mixed blackbird flock attacking a field of California rice. Stomach analyses showed that red-winged, tricolored, and yellow-headed blackbirds eat more rice than Brewer's blackbirds and cowbirds. (Photo by Frederick T. Crase)

May but with only a muddy or spongy bottom by July. Habitat selection was assessed by relating breeding success to discriminable features of the habitat in territories, and was based on the assumption that these characteristic features or "signposts" of the environment provide the recognition stimuli that guide redwings in selecting habitat for breeding. During each of five successive 14-day periods (1 May–9 July), data were systematically collected on 21 selected variables that describe male territories: 15 descriptors of structural and spatial features (e.g., amount of cattails and other emergent plants of various heights, linear edge of vegetative types and of form classes) and 6 descriptors of reproductive success (e.g., numbers of nests, eggs, hatchlings, fledglings). Territories were mapped, nest searches made, and vegetative measurements taken during each 14-day period.

Data analysis indicated that territory size and reproductive success were correlated positively with the presence in territories of large amounts of four of the descriptors examined: cattails, total linear edge of vegetative types (interface between plant species), total linear edge of forms (interface between plant form classes), and wide-leafed emergents greater than 1 meter in height. These key features were actively sought and defended by male redwings. They appear to be four of the most important recognizable features that govern site selection in heterogeneous wetland areas and influence redwing production.

Roadside census underestimates population of territorial male redwings.—In an evaluation of the Hewitt roadside method, used extensively to calculate the population of territorial male redwings from a slowly moving vehicle, density estimates per route averaged 28% lower than those obtained by walking the same routes during the same week (30 April–4 May 1973) in an Ohio study area. Walking counts over eight 4-mile routes indicated an average density of 16.5 male redwings per 100 acres; in contrast, the average density was 11.9 males per 100 acres for the eight routes based on a total of 120 Hewitt estimates from five biologists, each of whom censused each route three times. In addition, two other routes censused by the Hewitt method a total of eight times had an average density estimate of 9.7 male redwings



Red-winged blackbird feeding on corn. Because of the damage to corn caused by this species, its numbers, movements, roosting behavior, nesting habitat, physiology, and reproductive biology are being investigated. (Photo by Brooke Meanley)

per 100 acres compared with a walk count finding of 14.2 male redwings per 100 acres.

These results support earlier field work which indicated that redwing territorial males vary in their probability of being sighted, and that this variability would result in underestimation of male density when the Hewitt method is used. The 1973 experimental work more clearly defines the limitations of the Hewitt method and should allow investigators to obtain more precise population estimates on a problem species.

Weather and fall migration of ducks.—Migrating birds pose a hazard to aircraft; being able to predict migration of large birds or large



Marking samples for damage assessment in a test of methiocarb as a bird repellent on cherries in Michigan. The test showed no difference in damage between treated and control plots. (Photo by Allen R. Stickley, Jr.)

numbers of birds may reduce this hazard. Analysis (at the University of Illinois under Service contract) of 21 years (1948–68) of data on numbers and movements of fall-migrating ducks shows that duck movements usually are not closely related to weather conditions at the time of departure. Arrivals at Peoria, Ill., and departures from Fargo, N. Dak., of seven species of ducks were quantified, based on weekly censuses taken from aircraft and on other relevant information. Weather data for the areas of departure (Fargo) and arrival (Peoria) were analyzed in depth to determine the importance of various weather factors relating to duck movements. In only 8 of 29 different analyses did weather account for as much as one-third of the migration movement. Late-migrating duck species, mallards and canvasbacks, appeared to be the most responsive to weather conditions, and earlier migrating species were less influenced.

Two patterns of weather influence were revealed: severe weather, e.g., snow, cold-front passages, and strong winds, tended to trigger movements of large numbers of waterfowl to continue fall migration southward; however, mild and fair weather increased movements of smaller numbers of ducks that presumably were ready behaviorally to continue migration as attested by their departure to fly the next leg of the fall migration corridor.

Tests of methiocarb for reducing bird damage to crops.—Convincing evidence of the efficacy of methiocarb (a chemical bird repellent) for protecting sprouting field corn from bird damage was obtained in tests in New York State in the spring of 1973. Damage to sprouts in eight control fields averaged 28 times that in eight fields with treated seed. The repellent, a powder consisting of 50% methiocarb, was applied to the seed in the planter hopper box at the rate of 1 part by weight to 100 parts of seed. The effectiveness, inexpensiveness, and ease of application of this material make this a potentially desirable method of bird-damage control.

In Michigan, 2 weeks after spraying methiocarb on high bush blueberries in 1973, investigators found no significant differences between bird damage in treated plots (7.2% loss) and untreated plots (9.5% loss). These results may have been due to one or more of the following reasons: (1) methiocarb is ineffective in repelling birds from blueberries, (2) methiocarb may have different levels of effectiveness depending on the amount and type of bird activity in blueberry plantings, and (3) birds may have been unable to distinguish treated from untreated areas because the plots were small and had indefinite boundaries to birds. Bird observations in six plantings revealed that robins, starlings, and grackles (in that order) were the major depredators; 12 other avian species were observed feeding on blueberries. Bird observations also indicated that small plantings (less than 10 acres) had considerably more bird damage than large plantings (30–40 acres).

Loss of cherries to birds was not significantly different between blocks of trees treated with methiocarb and untreated blocks in two Michigan sweet cherry orchards in 1973. Total cherry losses in one orchard were estimated at 5.0% in treated blocks (14 trees per block) compared

with 4.2% in untreated blocks. Losses in the other orchard were estimated at 13.6% in treated blocks (17–53 trees per block) compared with 19.2% in untreated blocks. These results may have been due to one or more of the following reasons: (1) methiocarb was ineffective, (2) birds did not distinguish between treated and untreated blocks, (3) bird pressure (0.81 bird per observation hour in one orchard and 0.31 in another) was too low to obtain good tests, and (4) an area-wide repellent effect occurred that kept birds out of both treated and untreated blocks.

Mode of effectiveness of bird repellents explored.—Repellents which produce a mild toxic reaction that can be associated with the taste of the material may be more effective than repellents that merely taste bad. Laboratory tests of red-winged blackbirds have indicated that repellents of the first type often cause delayed aversion. The delay probably represents the time between eating the food and the occurrence of the reaction, plus the time needed to asso-

ciate the two events. Probably because of the illness-producing properties of these conditioning repellents, birds in laboratory tests appear to be more highly motivated to utilize alternate foods than when they are exposed to foods protected by simple taste repellency. Tests with methiocarb, a candidate bird-repellent, indicate that it acts as a conditioning repellent.

Soil applications of surfactants not harmful to crops.—Treatment of winter blackbird roosts with potassium oleate and sucrose monolaurate is a promising method of reducing crop-depredatory populations. The surfactants were applied to plots at rates from 170 to 678 pounds per acre, levels as great as four times those used to treat blackbird roosts. Yield and quantity of rice, cotton, and soybeans grown on the plots were not affected by applications of the two chemicals to soils subsequently planted to these crops. The tests were part of a continuing effort to find effective blackbird wetting agents that are environmentally safe.



Measuring lengths of corn kernel rows in the laboratory (left) and assessing bird damage to corn in the field (right). Data from these and other methods of assessing damage will be compared for accuracy, precision, and efficiency. (Photos by Allen R. Stickley, Jr.)

Wetting agent for roosting blackbirds.—Bioassays conducted on red-winged blackbirds at the Gainesville, Fla., Field Station showed that the median acute oral and dermal lethal doses for Tergitol 15-S-9 Nonionic were very low, only 0.9 and 19.9 ml/kg, respectively. This wetting agent has been successfully field-tested as a safe means of physiologically stressing blackbirds and starlings in roosts.

Tergitol 15-S-9, sprayed in solution by airplane on roosting blackbirds and starlings, was registered in February 1974 by EPA (Environmental Protection Agency) for use by or under supervision of government agencies trained in bird control. This culminated several years of research effort in laboratory and field testing to demonstrate efficacy and safety.

Comparative studies of liver microsomes of redwing and rat.—Little is known about ultrastructural morphology of liver parenchyma or foreign compound metabolism by liver microsomes of most wild birds. Foreign compounds are metabolized, transformed, and generally detoxified in the liver. These processes are catalyzed by microsomal enzymes, among which

mixed-function oxidases (MFO's) play an important role. These enzymes exist in liver cells in smooth and rough endoplasmic reticulum, which, when isolated by ultracentrifugation, are called microsomes. Enzyme activity of MFO's generally differs among species. Therefore, studies are being conducted at the Gainesville, Fla., Field Station to discover those quantitative, and possibly qualitative, species differences that may be exploited for developing selective control measures for depredating birds.

Comparative studies have shown that the activity of three liver MFO's investigated was significantly lower in the red-winged blackbird than in the laboratory albino rat. Thus, compounds dependent upon the activity of these MFO's for detoxication would be eliminated less efficiently in the bird than in the rat, and should produce more physiological stress or be more toxic to the bird than to the rat.

Electron microscopy showed that smaller quantities of endoplasmic reticulum occurred in redwing liver parenchyma than in that of rats. This may partially explain the species differences observed in the activity of the MFO's.

BIOLOGICAL MONITORING

Denver Wildlife Research Center

Methyl parathion affects nesting success of ring doves.—Since the mid-1960's, the use of organochlorine pesticides in the United States has leveled off while the use of organophosphate pesticides has steadily increased. Of the latter, methyl and ethyl parathion are widely used, and may be sprayed repeatedly on croplands throughout the growing season. This is the season when many wild birds living in croplands are nesting.

To determine if sublethal exposure to methyl parathion could affect reproduction, three groups of ring doves were randomly assigned to be fed a diet containing 30 ppm of the compound: (1) throughout the total reproductive period; (2) after laying of the first egg; and (3) after hatching of the first egg. A fourth group was given untreated feed. In the affected groups, hatchability of eggs laid was reduced by the treated diet; the total treatment group

hatched 58% and the treatment-after-laying group, 77%, compared to the controls which hatched 96%. The mean number of young per pair raised to 21 days of age was reduced by 38% for the total treatment group, by 47% for the treatment-after-laying group, and by 25% for the treatment-after-hatching group when compared to controls. Body weights of young from treatment groups raised to 21 days of age were also lower than the controls. Controls averaged 112 g; total treatment, 105 g; treatment-after-laying, 98 g; and treatment-after-hatching, 98 g.

These results show that sublethal intake of methyl parathion can adversely affect ring dove reproduction in several ways. The degree to which this occurs in the many species of wild birds inhabiting farmlands and other sprayed habitats is unknown.

Effect of parathion on avian salt glands.—Studies with the avian salt gland begun in 1972

were continued in 1973-74 to establish parameters by which this system can be used as a sensitive *in vivo* model for studying the effects of sublethal levels of pesticides. Following preliminary studies showing that cholinesterase-inhibiting pesticides had marked effects on salt gland function, one of these pesticides, ethyl parathion, was selected for more detailed studies.

Parathion was administered in feed to newly hatched mallards at 25, 15, or 7.5 ppm. Birds were divided into four groups—with or without parathion, and with or without salt in the drinking water (activated versus inactivated salt glands). Each test was scheduled for 3 weeks, with a severe salt stress (injection of 5% salt solution at 25 ml/kg of body weight) and collection of salt gland secretions planned at the end of each week. However, parathion was unexpectedly toxic, and high mortality forced termination of the 25-ppm test after the first salt stress and the 15-ppm test after the second salt stress. Significantly fewer parathion-treated birds responded to the salt injections by producing measurable salt gland secretions at 25 and 15 ppm than controls, and those that responded secreted significantly smaller volumes and lower sodium ion concentrations at 25 and 15 ppm and during the first challenge at 7.5 ppm. Parathion inhibited cholinesterase activity in the hypothalamus and salt gland and increased ATPase activity in the glands of birds given salt in their drinking water.

These results clearly demonstrated that parathion exposure, even at very low levels, inhibits salt gland function in juvenile mallards. Since these glands are the bird's main route of salt excretion, their impairment could lead to salt intoxication in marine habitats. The specificity of the responses following a salt stress indicates that the salt gland may be a sensitive bioassay system in evaluating pesticidal effects.

Blood samples—an index to DDE exposure.—Traditionally, organochlorine residue levels in wildlife have been measured by analyzing adipose tissue or whole-body composites. Thus, only dead animals can be analyzed. This limits field monitoring programs to those species that are not endangered and places obvious restrictions on repeated residue sampling in laboratory animals. Killing the animal would not be necessary if residue levels in small samples of



Collecting nasal salt gland secretions from mallards fed clean diets and diets containing pesticides. (Photo by Milton Friend)

blood adequately represented those in fat (a relationship shown in epidemiological studies of human pesticide exposure). To explore this concept in wildlife, a 12-month study was conducted of DDE residues in blood and fat of treated mallards. Overall, there was a correlation (r) of 0.93 between paired blood samples and fat samples taken by biopsy from the same birds each month. Half of the test birds were subjected to surgery and half to periods of starvation, but neither of these stresses significantly affected the blood-fat correlation. These data indicate that blood is as suitable as fat to determine DDE exposure in birds.

Grasshopper insecticides and wildlife in a rangeland ecosystem.—An ecosystem study is being conducted to determine the overall effects of spraying grasshopper insecticides on rangeland. In June 1972, 320 acres of short-grass prairie were sprayed with toxaphene, 320 acres were sprayed with malathion, and 320 acres were left untreated. In cooperation with the International Biological Program, Grassland Biome, data have been gathered on resident birds (populations, nest success, and food habits), resident mammals (populations and reproduction), arthropods (populations and biomass), vegetation (species standing crop



The effect of grasshopper insecticides on rangeland wildlife and the ecosystem is being investigated on the Pawnee National Grassland in cooperation with the International Biological Program, Grassland Biome. Arthropod numbers and biomass are sampled with a "quick-trap" apparatus to determine availability of invertebrate food for wildlife (top). A conspicuous breeding bird of the short-grass plains is the male lark bunting (bottom). (Photos by Lowell C. McEwen)

and production), decomposition (rates), and insecticide residues (in animals, plants, and the environment). When the field observations are completed in 1974, data will be assembled to provide a picture of the total impact of insecticides introduced to a relatively simple ecosystem.

Preliminary findings include: (1) a significant decrease in total insects and other arthropods following the malathion and toxaphene treatments, (2) significant reduction in breeding bird populations from toxaphene, and (3) a

lack of response of plant biomass to removal of plant-feeding insects and other arthropods on the insecticide-sprayed areas. Later data will indicate recovery rates of affected animal populations, food habits changes, residue persistence, and overall productivity effects. This study will not only provide data on the effects of pesticides on rangeland, but will serve as an example of pesticide effects on ecosystems in general.

Population status of the California brown pelican.—Continuous population data on the endangered brown pelican of the Pacific Coast have been obtained since 1970. Aerial surveys of breeding pelicans in 1974 revealed three generally distinct breeding population segments: (1) the northern segment (10% of the population) breeding on vegetated islands off the California and Baja California Pacific coasts; (2) the Gulf of California segment (75%) in Mexico, including one colony on the west coast of southern Baja California, nesting on desert islands; and (3) the southern segment (15%), nesting in mangroves and other trees on the Sinaloa coast of Mexico.

The size of the breeding population, reproductive success, and juvenile mortality of pelicans were found to vary considerably from area to area and from year to year over the 5-year period. For example, in the Gulf of California, nesting success of undisturbed pelicans averaged about 0.9 to 1.1 young fledged per nest attempt in 1970, 1972, and 1974; about 1.5 to 2.0 young in 1971; and almost 0.0 in 1973, a year of nearly complete reproductive failure for many species of seabirds in the Gulf, possibly due to a shortage of food fish. In the northern population segment, nesting success never exceeded 0.3 young fledged per nest attempt until 1974, when the average rose to 0.7. This improvement followed a measurable decrease in DDE contamination when a California chemical plant was closed.

Marking studies have shown some population interchange, particularly of juveniles. Pelicans from the southern segment generally remain near their natal colonies or move south. Those from the Gulf of California usually concentrate at feeding areas off the coast of Sonora and Sinaloa following breeding; but in years of food abundance on the California coast, as much as 20 to 30% of this population may move north, where they intermix with the northern



In the Gulf of California, 1973 was a year of reproductive failure for brown pelicans and many species of coastal birds. These eggshells of normal thickness were destroyed by western gulls after the pelicans abandoned the nest. (Photo by D. W. Anderson)

population segment, and where they may acquire heavier pesticide residues than birds remaining farther south.

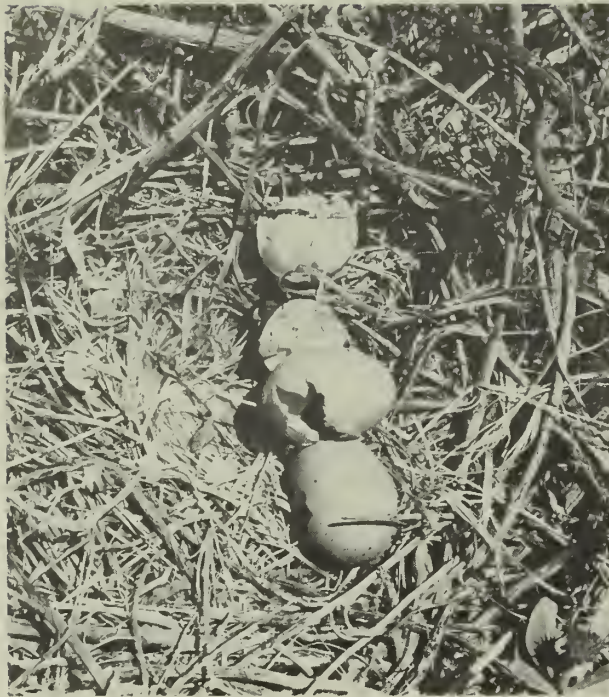
Presently, the northern population is clearly declining; its inadequate recruitment appears largely due to the depressive effects of DDE and other pollutants on reproductive success. The Gulf of California and southern populations appear to be threatened more by human disturbance to nesting colonies and inadequate food supplies resulting from heavy commercial fishing operations.

Bird mortality continues in Texas rice fields.—In late March 1974, another goose kill occurred in rice fields on the Garwood Prairie, Colorado County, Tex. Sixty geese (58 snows, 1 whitefront, and 1 Canada) were found dead or sick in the study area during the northward migration of geese that winter. Fifty-two geese were found dead or sick in the same area in

1972, and 180 in 1971. For these 3 years, 80% of the geese found dead or sick were males; in 1972 and 1974, 93% of the males were immature. Each year mortality of geese followed flooding of rice fields planted with rice seed treated with aldrin and usually a fungicide.

In 1974, rice seed planted on the Garwood Prairie was treated with aldrin and a diazole fungicide. Brains of 13 of the dead geese were analyzed for dieldrin (the primary metabolite of aldrin). Dieldrin averaged 9.7 ppm with a range of 2.1 to 15.0 ppm, high enough to implicate aldrin/dieldrin as the cause of death.

White-faced ibis nesting problems on the Texas coast.—White-faced ibis populations in Texas have fluctuated since a study was begun in 1969, but the overall trend has been downward. A 1973 aerial survey of the Texas coast showed that numbers of nesting adults were low at most of the traditional nesting areas.



White-faced ibis (top) and abandoned nest with broken thin-shelled eggs (bottom). Thin-shelled eggs are typical of many nests of this species on the Texas coast. (Photos by Kirke A. King)

Observations at two colonies on the central coast revealed that the ibis population is at a 4-year low, down 73% from 1972.

In 1973, 28 dead adult ibis were found at one study area where only 6 were found dead in 1972. Eleven of 49 marked nests (23%) were deserted before the eggs hatched and 29% of

the remaining active nests contained one or more dead young. Mortality of juveniles more than 1 week of age was heavy, and few young were fledged. The recovery rate of dead young with bands indicated a tenfold increase in mortality from 1972 (10% vs. 1%).

Late nesting or possible renesting of ibises failed to improve the generally unsuccessful breeding season because the late nests were even less successful than the earlier ones, and a greater percentage were abandoned or contained crushed eggs. Eggshell thickness averaged 0.264 mm for late nests and 0.293 mm for early nests. These values are about 20 and 11% less than those of museum specimens collected before 1945.

Brown pelican numbers continue low on the Texas Gulf Coast.—Less than 100 brown pelicans remain on the Texas coast in a population that once exceeded 5,000 birds. Reproduction in recent years has been poor, and breeding pelicans fledged only 28 young from 1964 to 1972. In 1973, of a total of 50 to 55 pelicans seen during the April-June nesting season, only six pairs attempted to breed and 11 young were fledged (on Carroll Island and San Antonio Bay). Unless nesting success improves, native brown pelicans on the Texas coast will disappear because of insufficient production.

Pesticides in larids on the Texas coast.—In 1973, a total of 29 adult laughing gulls were found dead on island colonies during the nesting season. Dieldrin residues up to 16 ppm were found in the brains of gulls collected in this area in 1972. Although numbers of adult gulls were about normal at two colonies, breeding pairs made fewer active attempts at nesting. At one colony, adults were more numerous than in 1972, but nest density was slightly lower. At the second colony, there were only 20 nesting attempts, versus 150 in 1972.

In 1973, Forster's terns experienced the lowest reproductive success of any seabird studied on the Texas coast. Adult terns made only desultory attempts at nesting in one study area, and all nests were abandoned before the eggs hatched. At another area, terns attempted to nest on five islands from May through July. Although hatching success was close to 50% in 50 marked nests on one island, nestling survival was very low and only two young terns survived to fledge. Nesting attempts on three

of the other islands were about as unsuccessful as on the study area, and only one island produced significant numbers of fledgling terns.

Low levels of dieldrin, DDE, and PCB's were found in tissues of seven tern chicks collected in 1972, indicating that the population is exposed to these compounds.

Analytical services support wildlife biologists.—In support of studies being conducted by wildlife biologists from the Denver Wildlife Research Center, Fisheries Services, Ecological Services, the South Dakota Cooperative Wildlife Research Unit, and several Management and Enforcement officers, the Denver Center's chemical laboratory analyzed some 2,500 samples in 1973–74. These analyses were performed on a wide variety of sample types including water, grain, vegetation, insects, birds, mammals, and fish; they resulted in over 12,000 separate qualitative and quantitative measurements of chlorinated and organophosphate insecticides, fungicides, assorted other pesticides and control chemicals, polychlorinated biphenyls, and metals.

New methods developed for heavy metals.—In a continuing effort to improve the efficiency and reliability of analytical methods used for heavy metals, an improved procedure has been developed for determining lead and cadmium. Basically, the procedure involves destruction

of the sample by dry ashing and a chelation cleanup step followed by a flameless atomic-absorption measurement technique called carbon rod atomization. This new procedure is much more sensitive and reliable at lower levels than the older method utilizing wet digestion and conventional flame atomic absorption.

Fish-Pesticide Research Laboratory

Screening of toxic chemicals.—The Fish-Pesticide Laboratory and its field stations examined the acute toxicity to fish of 76 chemicals and chemical formulations—insecticides, herbicides, fungicides, lubricating oil additives, flame retardants, plasticizers, a flocculating agent, and forest fire retardants. The chemicals were selected for testing for various reasons: they were intended for application to water, they might be accidentally applied to water, their residues were detected in fish, or they might be present in agricultural run-off or industrial effluent discharge.

A synthetic pyrethrin insecticide, RU-11679, was the most toxic chemical tested, with a 96-hour LC_{50} (the concentration lethal to 50% of the experimental animals) in the range of 0.1 to 1.0 $\mu\text{g/l}$. In general, insecticides were the most toxic compounds with LC_{50} 's ranging up to 1,000 $\mu\text{g/l}$ and many herbicides had LC_{50} 's in excess of 100,000 $\mu\text{g/l}$. Of the industrial compounds, dibutyl chlorendate, a candidate plasticizer, appears to be relatively hazardous if aquatic contamination occurs. Although it is not toxic at 100 mg/l at 96 hours, continued exposure produced increasingly toxic effects; the LC_{50} was 6.4 $\mu\text{g/l}$ after 30 days of exposure.

Toxicity of herbicides being investigated.—The probability that herbicides will appear more frequently in aquatic habitats is increasing because of their use to control aquatic vegetation in irrigation and recreational waters, increased use in minimum tillage agricultural practice, and improved analytical detection methods.

The toxicities of diuron and Tordon were increased 2 to 10 times by increasing water temperature from 5 to 25° C. However, toxicities of xylene, Ureabor, and 2,4-D DMA were not affected by temperature, and Aquathol K and Emulsamine E-3 were more toxic at lower temperatures. Water hardness had little or no effect on toxicity of diuron, Tordon, or xylene.



Water baths and pH meters are essential tools in determining wildlife exposure to organophosphorous insecticides. Their use permits quantitative assessment of cholinesterase inhibition by the insecticides. (Photo by James E. Peterson)

Although Tordon is not highly toxic to fingerling lake trout, chronic exposures of their eggs and fry to only 35 $\mu\text{g/l}$ reduced incubation time, increased yolk absorption time, and reduced growth by 28% and survival by 52%.

Aquathol K and Bolero are experimental aquatic herbicides. Aquathol K is intended for control of aquatic weeds in irrigation and recreational waters and Bolero for use in rice fields. Tests of Aquathol K at recommended rates of application in artificial streams showed that residues of endothal (the active ingredient) in rainbow trout were less than 0.02 $\mu\text{g/g}$ at 1 and 12 hours after exposure. Bolero was tested for bioaccumulation in swamp crayfish, a commercial gourmet food, and in scuds, midge larvae, burrowing mayflies, channel catfish, fathead minnows, bluegills, and longear sunfish. Test concentrations were based on half-life of Bolero under field conditions. Residues in crayfish were 2 to 30 times the concentration in water, but declined 50% in edible tissue after the crayfish were held for 10 days in clean water. Other invertebrates had similar uptake rates, but fish accumulated maximum residues 57 to 470 times the water concentration. Nevertheless, 50% of the residue was lost within 24 hours after the fish were transferred to pesticide-free water.

Forest insecticides.—Research was continued on forest insecticides that have been under consideration as substitutes for DDT. The toxicity of Zectran, Volaton, Dylox, pyrethrum, RU-11679, Guthion, and SBP 1382 was tested individually and in paired combinations to estimate potential synergism in rainbow trout. Combinations of Dylox and Guthion, or Volaton plus RU-11679 were synergistic. The other combinations appear additive or antagonistic, and the combination of Zectran with Volaton was highly antagonistic. The exposure of brown trout to sublethal concentrations of chlordane (organochlorine insecticide) doubled their resistance to organophosphate insecticides such as Volaton, methyl parathion, leptophos (Phosvel), and Guthion.

Zectran appears to be relatively nontoxic over a wide range of fish species, including Pacific and Atlantic salmon, trout, bluegill, and yellow perch. The 96-hour LC_{50} values generally fall between 15 and 25 mg/l . However, sac-fry seem to be more sensitive and fertilized trout

eggs are 10 times more susceptible. Also, Zectran is 5 to 20 times more toxic in waters of pH 9.0 to 9.5 than in less alkaline waters. In addition, the toxicity of Zectran increases for 3 to 4 weeks after application—particularly at pH 8.5 to 9.5—and then decreases. The initial increase in toxicity is probably due to the formation of more toxic intermediate degradation products. These degradation products were isolated by Charles Hosler, University of Wisconsin at LaCrosse, and identified by GC-mass spectrometry at the Fish-Pesticide Research Laboratory as 2,6-xyloquinone, 4-N,N-dimethyl-3,5-xyleneol, 2,6-xyloquinol, and 4-amino-3,5-xyleneol. The last compound is 40 times more toxic to bluegills than Zectran. The significance of these intermediate products is unclear, but they would very likely be below toxic concentrations at the recommended application rates. Pond applications of Zectran at the Fish-Pesticide Research Laboratory at the recommended rates indicated no serious effect on insects or reproduction of fish.

Trout appear 500 to 1,000 times more sensitive to leptophos than to Zectran. In contrast, warmwater fish such as bluegill, yellow perch, and fathead minnows are not much more sensitive to leptophos than to Zectran. The toxicity of leptophos is not affected by pH and it degrades through one half-life in about 2 weeks. Tests with a laboratory food chain indicate that about 10% of the leptophos residue in a fish's food, such as daphnids, is transferred to the fish.

Atlantic salmon resistant to Zectran.—Atlantic salmon stocks have declined over the years and serious attempts are being made to improve the fishery. Concern over the effect of various insecticides on Atlantic salmon production stimulated research on potential forest insecticides in particular. The compounds tested and the 96-hour LC_{50} 's ($\mu\text{g/l}$) at 12° C are as follows: RU-11679 (synthetic pyrethroid), 0.41; Guthion, 2.2; Volaton, 380; Dylox, 2,970; and Zectran, 22,300. Fertilized eggs were five times more resistant than fingerlings to Guthion, and sac fry were eight times more resistant at 7° C than at 12° C. Continuous exposure of fingerlings to Volaton and Zectran reduced LC_{50} values by 60 to 70%. Current research is designed to determine whether Atlantic salmon containing DDT and DDE

residues are more susceptible to other pesticides, or less so.

Mosquito control agents appear relatively safe.—The Fish-Pesticide Research Laboratory continued cooperative studies with the USDA Biological Control Laboratory, Columbia, Mo., on host specificity of the nematode, *Reeismermis nielsenii*, the preparasitic stages of which infect mosquito larvae. Eggs, yolk-sac fry, and swim-up fry of rainbow trout, channel catfish, largemouth bass, and fathead minnows were not infected by parasite concentrations 1,562 times the field application rate of 5 million preparasites per acre-foot of water. In fact, some swim-up fry foraged on the free-swimming parasites. Also, we could find no evidence that daphnids, scuds, or aquatic oligochaetes were penetrated by the parasites.

Abate has shown promise for mosquito control in many parts of the United States, including high-elevation marsh lands. Although it is relatively nontoxic and appears to degrade rapidly, it is not known whether it would influence reproduction of salmonids if it were applied before spring spawning. To obtain information on this point, we exposed adult cutthroat trout to anticipated field concentrations of 67.5 or 135 $\mu\text{g/l}$ Abate at 3-week intervals during the 4 months before spawning. The exposures lasted 6 days, but were reduced one-seventh each day to simulate degradation. Egg production, hatching success, and fry survival were similar between treated and control fish. The sensitivity of eggs, fry, or fingerling cutthroat trout to Abate is being investigated.

Forest fire retardants relatively nontoxic.—The U.S. Forest Service uses two classes of fertilizers—Phos-Chek 202 and 259, and Fire-Trol 100 and 931—that are formulated to fight forest fires. The formulations were tested for their acute toxicity to scuds, fingerling bluegills, fathead minnow, and largemouth bass, and to various life stages of rainbow trout and coho salmon. The acute, static 96-hour LC_{50} 's for Phos-Chek formulations ranged from 40 mg/l for scuds to more than 1,500 mg/l for fish. In comparison with Fire-Trol, the toxicities of Phos-Chek ranged from similar to more than seven times higher. Temperature had little effect on toxicity, but the pH of contaminated water may influence toxicity because of the ionized ammonia released from the fertilizer.

Polychlorinated biphenyls, phthalate esters, and fish.—Residues of polychlorinated biphenyls (PCB's) and, to a lesser extent, phthalates have been detected in wild populations of fish as well as in synthetic fish foods. The long-term impact of these residues is not clear, although one report shows that residues of 0.5 $\mu\text{g/g}$ Aroclor 1254 (PCB) or more in Atlantic salmon eggs reduces survival of young. The residues frequently found in trout diets (0.05 to 2.0 $\mu\text{g/g}$) could produce residues of this general concentration in the eggs. In 1973 four groups of 3-year-old cutthroat trout were fed rations containing 0, 0.05, 0.3, or 1.5 μg of Aroclor 1254 per gram of food (wet weight), at the Jackson National Fish Hatchery, Wyo. After 150 days of treatment, the PCB had no effect on adult growth or egg production. However, hatchability of eggs from treated groups was significantly reduced; the hatch was 94% for controls and 61, 78, and 87% for the three treatment groups. All of the fry that hatched survived and were placed on uncontaminated rations. However, their growth rates were still significantly slower than that of control fish after 90 days.

A study analogous to the PCB investigation was conducted with di-2-ethylhexyl phthalate (DEHP). The food concentrations were 0, 0.1, 0.3, and 1.0 $\mu\text{g/g}$ of food. The DEHP had no effect on adults, number of eggs produced, or on egg hatchability, although eggs from one female fed at 0.1 $\mu\text{g/g}$ had a high incidence of deformities. The growth of fry from DEHP-treated parents lagged significantly behind controls. Other studies showed that DEHP did not alter length or weight of fingerling brook trout, but did change the amino acid and collagen content of backbone. Low dosages of DEHP increased collagen content and high dosages decreased it. Some degeneration and necrosis of the heart and liver were also caused by DEHP.

Inquiry into the degradation of phthalic acid esters indicates that microorganisms from freshwater sediments degrade these chemicals, particularly under aerobic conditions. Degradation proceeds through a series of intermediates and may result in cleavage of the benzene ring. Likewise, fish also degrade phthalates and the end products may be incorporated into fatty acids.

Substitutes for PCB's may also be hazardous to fish.—The discovery that PCB's, which are used as oil additives, flame retardants, and plasticizers (among others), have become widely distributed in aquatic environments and elsewhere has stimulated research into possible substitutes. The Fish-Pesticide Research Laboratory tested the triaryl phosphates, Pydraul 50-E and Houghto-Safe 1120, which are used as flame retardant additives in hydraulic fluids. Both compounds are toxic to trout, bluegills, channel catfish, and fathead minnows in the range of 100 to 10,000 $\mu\text{g/l}$. However, at sublethal concentrations of 10 to 100 $\mu\text{g/l}$, the fish become immobilized and some have broken backs. Nevertheless, they continue to live for an extended period before succumbing to secondary causes. These limited results suggest a need for more intensive studies should surveys underway by other agencies reveal the presence of these materials in aquatic habitats.

Toxaphene affects growth and reproduction of fish.—Although use of organochlorine insecticides has been reduced in recent years, some—including toxaphene—are still used extensively. From 30 to 40 million pounds of this insecticide are applied annually on crops and livestock in the United States. Since the use of DDT was curtailed, toxaphene has often been used to replace it, both alone and in combination with other insecticides. We therefore began cooperative studies in 1972 with the U.S. Environmental Protection Agency (EPA) to establish water quality criteria and standards for toxaphene, and to assist the Fish and Wildlife Service in evaluating toxaphene's impact on fishery resources.

Toxaphene is acutely toxic to fish; the lethal threshold concentrations for brook trout, bluegills, fathead minnows, and channel catfish range only from 0.5 to 15.2 $\mu\text{g/l}$. Earlier, we found that growth of adult brook trout was reduced during continuous exposure to 0.29 and 0.50 $\mu\text{g/l}$ toxaphene and the added stress of natural spawning caused extensive mortalities of adults at these concentrations. Growth and survival of fry were affected adversely at concentrations down to 0.039 $\mu\text{g/l}$ and toxaphene was bioaccumulated 5,000 to 21,000 times the water concentration.

Because toxaphene is used extensively in the southeastern United States, we tested it against

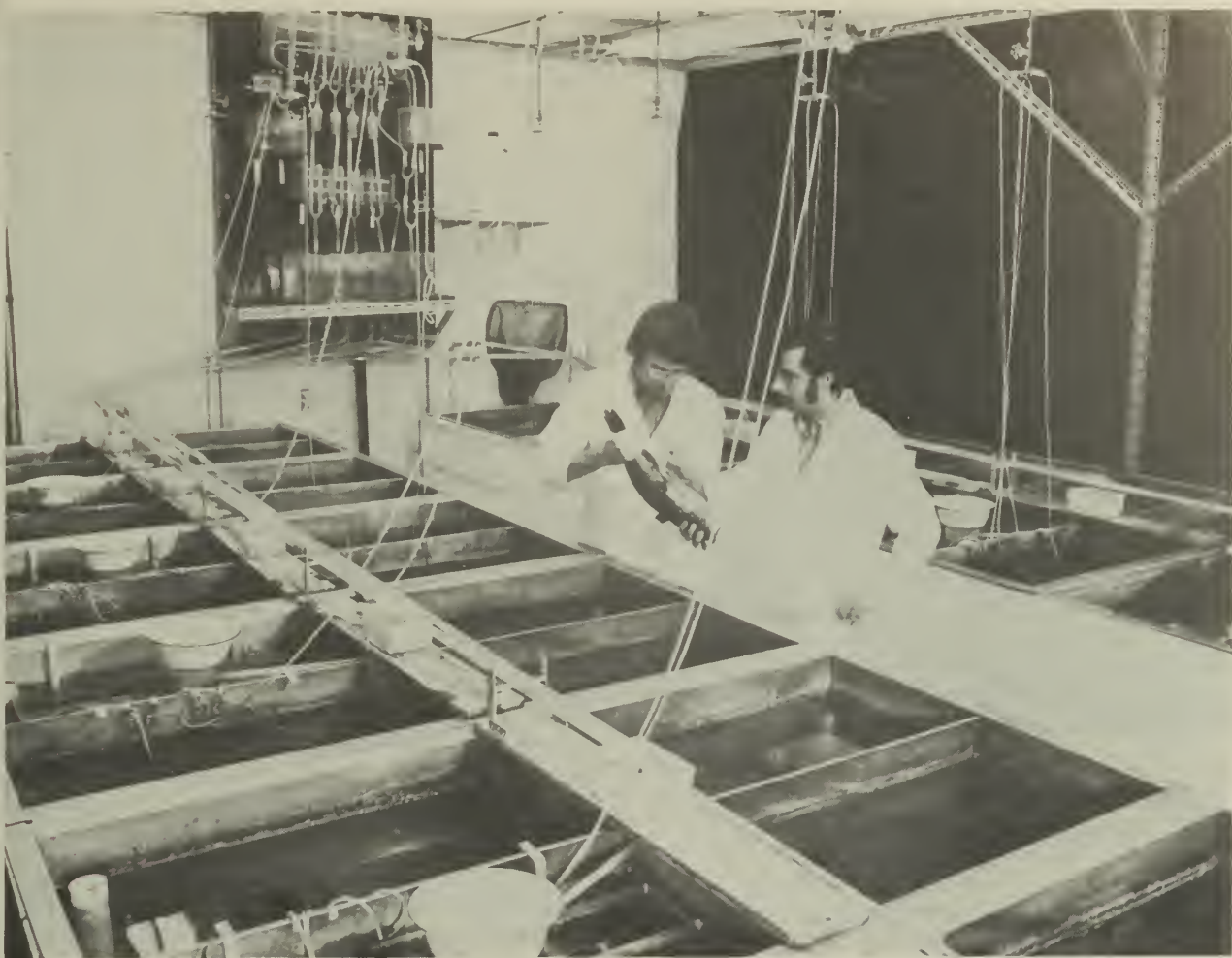
fathead minnows, an important forage and bait species, and against channel catfish. Ten-day-old fathead minnow fry were exposed continuously to concentrations of 0.06 to 122 $\mu\text{g/l}$ of toxaphene. The fish were reared at a constant temperature of 24° C and under regulated photoperiod approaching natural lighting. Growth of the fish was not affected in up to 90 days of exposure. Between 90 and 150 days, however, the growth of all fish exposed to toxaphene was significantly less than that of the control fish. At this time, toxaphene residues were accumulated in excess of 90,000 times those in the treated water. Residues in fish exposed to the highest concentration averaged 94 $\mu\text{g/g}$.

Two-year-old channel catfish were also exposed continuously to concentrations of 0.023 to 0.51 $\mu\text{g/l}$ of toxaphene for 4-1/2 months prior to spawning. Spawning occurred naturally through manipulation of photoperiod and water temperature and 85% of the fish reaching sexual maturity spawned. Adults were not affected, but hatchability of eggs from adults exposed to 0.51 $\mu\text{g/l}$ was reduced slightly and preliminary analysis indicates that growth of fry at 0.22 and 0.51 $\mu\text{g/l}$ toxaphene was slowed.

Toxaphene may also have an adverse effect on important fish foods. Concentrations of 10 $\mu\text{g/l}$ or greater inhibited emergence of midge larvae, but this level is well above those affecting reproduction or growth in fish. However, greater resistance of midge larvae could enable them to accumulate significant residues. Reproduction of daphnids was reduced by half when they were exposed to 0.12 $\mu\text{g/l}$ toxaphene for 21 days, and the no-effect concentration was 0.007 $\mu\text{g/l}$.

Toxaphene concentrations of 0.04 to 0.25 $\mu\text{g/l}$ are detrimental to the productivity of fish and their food, and contamination of waters due to run-off, leaching, or spraying should be avoided. Unfortunately, these concentrations are difficult to detect analytically. However, tissue residues exceeding 0.4 to 1.8 $\mu\text{g/g}$ in salmonids may be associated with reduced growth and reproductive success and over 5 $\mu\text{g/g}$ may cause reduction in growth of channel catfish fry.

Detection of toxaphene residues is difficult because the insecticide is a mixture of isomers, and contaminants such as PCB's interfere in the analyses. Multiple cleanup methods using



Sublethal effects of toxaphene on growth and reproduction of channel catfish are determined in this multiple concentration, flow-through diluter with controlled light and temperature.

gel permeation, Florisil, and silicic acid are necessary for reliable analyses with gas chromatography. However, the best analyses were accomplished by using chemical ionization mass spectrometry. These spectra revealed several homologous series of chlorinated camphenes containing four to nine chlorines per molecule. The numerous isomers are derived from each degree of chlorination.

Biochemical manifestations of toxaphene in fish.—Collagen is the major fibrous protein of all vertebrates and serves as the major component in the organic matrix of connective tissue and bone. The proper ratio of collagen and minerals is essential for rigidity and flexibility of bone, as well as general development and maturation.

Brook trout eggs and fry were exposed to toxaphene for 90 days and young fathead minnows for 150 days. Analyses of backbones showed that synthesis of hydroxyproline, the major amino acid of collagen, was inhibited during the first few weeks of exposure to toxaphene at concentrations of $0.039 \mu\text{g/l}$ or more. In older fish, collagen synthesis was reduced at all concentrations of toxaphene by the end of the exposure period and appeared correlated with reduced growth. The earliest inhibition of collagen synthesis occurred at the highest toxaphene concentrations and preceded observable reductions in growth.

In general, the net effect of toxaphene in fish was reduced collagen synthesis and increased mineralization of the backbone and whole body.



Effects of toxaphene on backbone structure. Radiographs A and B are of fathead minnows exposed to low toxaphene concentration (55 mg/l) and subjected to a 60-volt electrical shock; radiograph C is representative of the control group (shocked, but not exposed to toxaphene). Arrows point to areas of backbone affected.

We postulated that this condition may cause the backbone of fish to be brittle and fragile, and, therefore, subject to breakage during times of swimming stress. We confirmed that the backbones of toxaphene-treated fish were more fragile by subjecting groups of toxaphene-treated and control fathead minnows to a sublethal electrical shock (60 volts, AC) and then examining the backbones by X-ray. A condition known as "broken-back syndrome" has been reported by other investigators in pond-reared fish, as well as in natural populations. The condition can be caused by a vitamin C deficiency, toxaphene, and probably other stresses that interfere with collagen synthesis.

Impact of 2,4-D DMA on fishes.—The compound 2,4-D DMA is used widely in control of aquatic vegetation. Although considerable research has been devoted to its efficacy and residues, little is known about its long-term

toxicology in fish, probably because it has a relatively low toxicity to fish, with a 96-hour LC_{50} in excess of 100 mg/l, or over 50 times the concentration usually applied to water.

Adult fathead minnows were exposed continuously to concentrations of 0.12 to 2.0 mg/l of 2,4-D DMA for 2 months before spawning. Such a rigorous exposure would simulate an effluent or closely spaced multiple applications of 2,4-D DMA. We observed no adverse effect of the herbicide on growth, survival, or reproductive success of the fish. However, all treated groups of fish spawned 1 month earlier than controls. Biochemical investigations of 2,4-D DMA-treated fish showed increased thyroid activity, which is indicative of stimulated metabolism and could account for earlier spawning. Measurements of backbone collagen and mineralization revealed effect similar to those found in fish exposed to toxaphene, though less severe.

Eggs of the American toad were also exposed continuously to 2,4-D DMA at concentrations of 0.6 to 10 mg/l throughout metamorphosis to adults. Egg hatch and growth and mortality of tadpoles were not affected by 2,4-D DMA, but rate of transformation from tadpoles to adults was 21 to 83% faster in groups exposed to 1.2 to 10 mg/l.

Although 2,4-D DMA appears relatively harmless, its stimulatory effect on spawning time must be considered in view of predator-prey interrelationships. Alterations in time of prey availability (form, size, and numbers) could disrupt food chains.

Registration research on 3-trifluoromethyl-4-nitrophenol and Bayluscide.—The chemical 3-trifluoromethyl-4-nitrophenol (TFM) was registered in 1964 for limited use as a larvicide to control lampreys in the Great Lakes. The EPA is presently renewing registration of TFM on an annual basis while research is being conducted to determine the effects of the lampricide on nontarget organisms.

The effect of TFM on yearling brook trout growth, reproduction, and mortality was determined under continuous exposure. The fish were exposed to 0, 0.7, 1.6, 3.3, 8.0, and 14.0 mg/l of the technical formulation of TFM. Growth was significantly reduced at the highest concentration after 120 days of exposure. Also, no spawning occurred and all of the adults died during spawning activities in the highest con-

centration. Egg viability and hatchability were reduced at TFM concentrations of 3.3 mg/l and higher. Growth rate of fry exposed to TFM for 9 days was reduced.

The results show that a continuous exposure of TFM is toxic to nontarget organisms at concentrations below those used in field applications. However, a continuous exposure of TFM to fish is an unrealistic approach in evaluating safety because the period of exposure of fish to TFM in field use does not exceed 12 hours at 20 mg/l. At present, EPA recommends that fish be continuously exposed to the pesticide for the duration of the study. Studies are being conducted to determine the safety of simulated use-patterns of TFM to brook trout.

Bayluscide is a molluscicide, but is sometimes used as a potent synergist for TFM. Therefore, it is also important to determine the effect of Bayluscide on nontarget organisms. Static toxicity tests show that the 96-hour LC_{50} 's for crayfish, scuds, and fourth instar midge larvae are 25.0, 3.2, and 0.52 mg/l, respectively. Bayluscide is about twice as toxic in longer-term, continuous exposure studies and a concentration of 0.38 mg/l reduces reproduction of daphnids by 50%. Emergence of adult midges is reduced 20% by a concentration of 3.2 mg/l. Scuds, daphnids, and midge larvae bioaccumulate ^{14}C -Bayluscide by only 3 to 55 times the water concentration.

Laboratory analysts assist other environmental agencies.—In 1973 and the first half of 1974, chemists of the Fish-Pesticide Research Laboratory have analyzed hundreds of samples for other Fish and Wildlife Service divisions, as well as for States. We are beginning our second year of investigations on striped bass along the east coast from Florida to New York. Eggs and adults collected in 1973 during spawning runs in Florida, Georgia, and South Carolina contained residues of toxaphene and chlordane, with lesser amounts of DDT and PCB's. In contrast, samples collected in North Carolina, Maryland, and New York contained significant residues of DDT and PCB's, but no toxaphene or chlordane. In some samples, PCB concentrations have exceeded by 10 times those thought to interfere with Atlantic salmon reproduction.

In spring 1974, brain samples collected by the Missouri Department of Conservation from migrating blue geese dying on State refuges

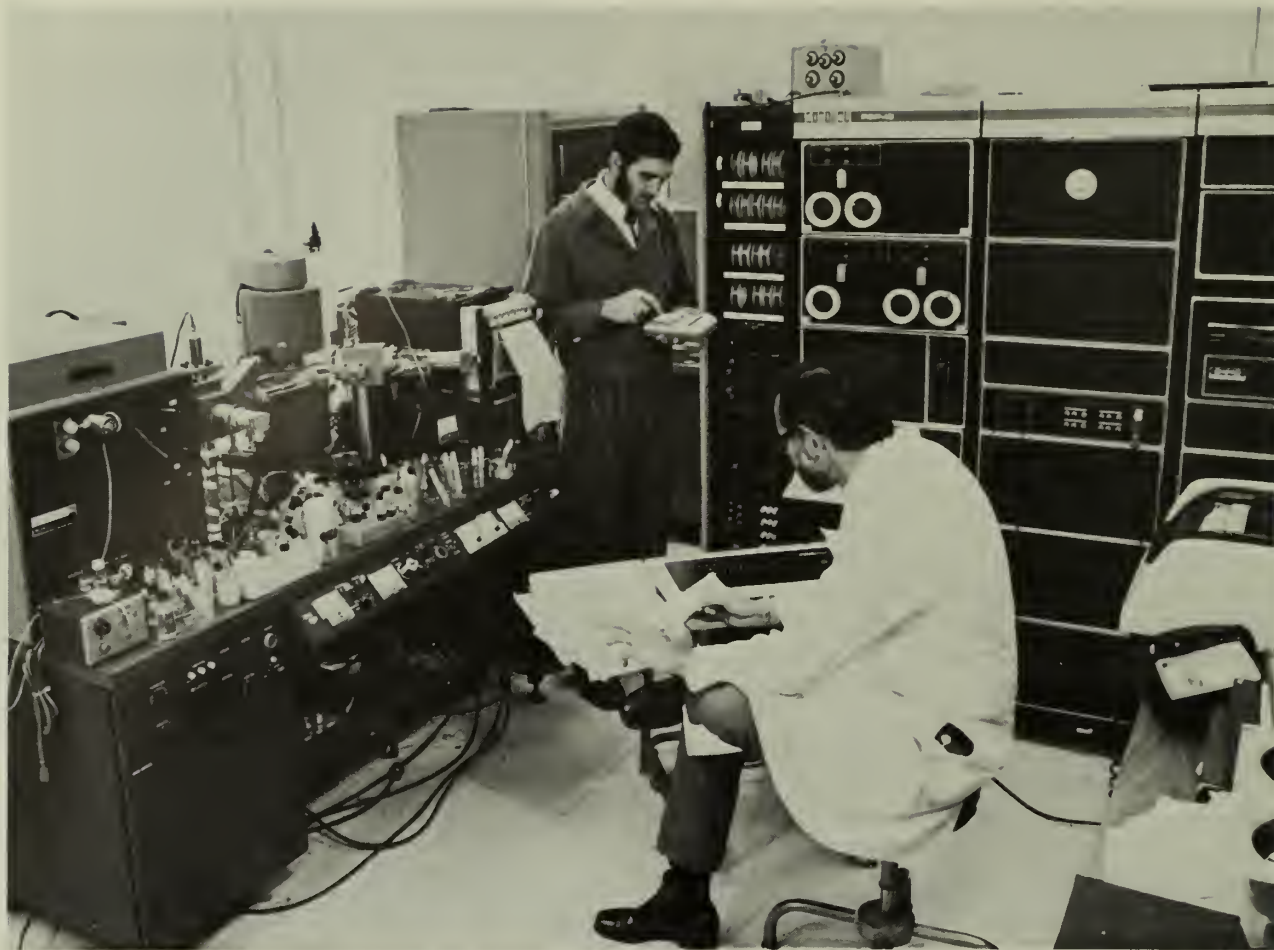


Automated gel permeation chromatography unit developed at the Fish-Pesticide Research Laboratory for separation of lipids and pesticides.

contained in excess of 20 ppm dieldrin. The geese are believed to have become contaminated while foraging in southern rice fields.

Other significant analyses showed that (1) organochlorine residues in channel catfish brood stock from several southwestern National Fish Hatcheries were relatively low; (2) DDT residues in lake trout fry from the Finger Lake Region, New York, were high (6.6 ppm); (3) PCB residues in fish from Morgan Lake, New Mexico (a power plant cooling lake), ranged up to 9 ppm; (4) average PCB residues have declined in fish collected in the National Pesticide Monitoring Program, but endrin residues increased in southern fish; and (5) residues of Mesurol, a potential bird repellent, degraded in water, mud, and rice by 90% within 2 weeks. We also continued international cooperation with the Organization for Economic Cooperation and Development to monitor fishery stocks with low, intermediate, and high residues of pollutants.

Full implementation of our computer data reduction system for gas chromatograms and



Computerized gas chromatograph-mass spectrometer in use at the Fish-Pesticide Research Laboratory.

the gas chromatograph-mass spectrometer, and greatly improved chemical separation technology have been major factors in our ability to analyze more and increasingly complex residues.

Wood preservative kills Missouri fish.—The Missouri Department of Conservation suspected that pentachlorophenol was responsible for several large fish kills in Missouri streams. Analyses of samples by gas chromatography-mass spectrometry gave positive confirmation of pentachlorophenol residues and the results assisted the State's prosecution of violators.

Toxicological investigations showed that pentachlorophenol was acutely toxic to rainbow trout, channel catfish, fathead minnows, and bluegills at concentrations of 10 to 100 $\mu\text{g/l}$ and that toxicity was not influenced by temperatures between 5 and 25° C. Continuous exposure

of rainbow trout sac fry to near sublethal concentrations delayed yolk absorption and reduced growth by 15%. These results suggest that pentachlorophenol may have long-term effects on fish not readily detected by acute toxicity tests.

Computerization of gas chromatograph-mass spectrometer complete.—The interfacing of a PDP-12 computer with a conventional electron impact gas chromatograph-mass spectrometer (GC-MS) at the Fish-Pesticide Research Laboratory was fully implemented by January 1974. A radioactivity monitor was also added. The entire integrated system now enables us to make simultaneous recordings and computer processing of chromatograms, radioactive peaks, and mass spectra. Depending upon molecular structure, residue complexity, and efficiency of cleanup procedures, we are able to

identify residues at concentrations as low as 0.05 to 1.0 $\mu\text{g/g}$. Typically, molecular weights of many aromatic compounds can be determined on 0.1 to 1.0 μg of chemical. Over the past 18 months, we identified more than 40 compounds, including 5 degradation products of Zectran, 2 degradation products of phthalic acid esters, and a number of phenol derivatives that may be metabolites of 2,4-D DMA. The system was a key factor in developing analytical methods for hydroxylated PCB's, and in identifying metabolites of hexachlorobenzene, a fungicide and industrial chemical, in fish. Also, we found that we could separate planar aromatic chemicals such as chlorinated naphthalenes (Halowaxes), biphenylenes, dibenzofurans, and dibenzodioxins from PCB's on Darco charcoal. We will analyze for these materials in samples from the 1973 National Pesticide Monitoring Program.

We are adding multiple ion detection capability to the GC-MS system that enables the system to concentrate on predetermined or desired ions and will permit us to make quantitative analyses of selected compounds within complex residue mixtures. However, residues of some materials such as saturated bicyclic hydrocarbons like toxaphene, or heterocyclic chemicals, are not readily studied by electron impact mass spectrometry. Our research with toxaphene necessitated development of improved sample cleanup procedures to separate lipids and PCB's. Then we used chemical ionization detection to perform mass spectral analyses at another laboratory. This type mass spectrometry ionizes the different molecules in toxaphene without fragmenting them beyond interpretation. Toxaphene in fish from the National Pesticide Monitoring Program and in red-winged blackbirds chronically exposed to toxaphene at the Patuxent Wildlife Research Center was confirmed in this manner. Toxaphene consists of at least 200 individual chemicals, but has 10 or 15 major components. Birds are apparently able to degrade toxaphene more readily than are fish. We have obtained a surplus mass spectrometer for constructing and testing a chemical ionization detector, and an even newer atmospheric pressure ionization detector. If successful, the atmospheric pressure ionization detector will enable us to detect and measure a considerably greater variety of chemicals.

Patuxent Wildlife Research Center

Carolina brown pelicans stage a comeback.—Pelicans in South Carolina reproduced normally in 1973 for the first time since 1969, when Service records began. Pelicans fledged 1.29 young per nest at Cape Romain National Wildlife Refuge and 2.03 at Deveaux Bank, both more than the number required to maintain the population. More than 2,700 young were fledged in the two colonies. Pelicans in a small North Carolina colony fledged 45 young from 26 nests. This was the 3rd year of a 5-year ecological study of brown pelicans and associated species at the Cape Romain National Wildlife Refuge. Conducted jointly with the Refuge staff, the research is designed to obtain baseline data and to appraise species differences in response to environmental pollutants.

Brown pelicans restored to Louisiana.—Louisiana's nesting pelicans were extirpated in the early 1960's, but scientific records of the disaster are scanty and do not reveal the cause. Restoration efforts begun in 1968 resulted in transportation of nearly 500 pelicans from Florida to Louisiana since that year. The birds began to breed in Louisiana in 1971, and in 1973 approximately 26 young were fledged from 50 nests. Organochlorine residues in the eggs are low and shell thinning is slight. The number of nests has increased each year, from 13 in 1971 to 28 in 1972 and 50 in 1973.

Kelthane increases mallard embryo mortality.—Kelthane at 10 ppm in the diet of mallard hens increased the mortality of embryos 25% above controls during the final week of incubation. Five ppm had no measurable effect on reproductive success. Kelthane is an organochlorine acaricide structurally similar to DDT.

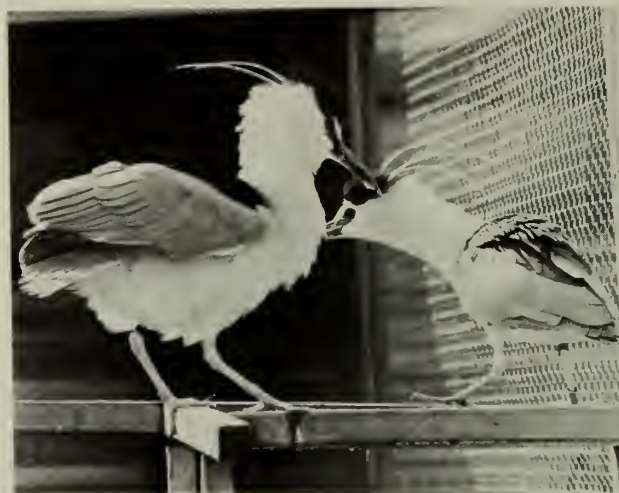
Mercury impairs mallard and black duck reproduction.—Mallard hens fed 3 ppm mercury (as methylmercury) in their diets during their first breeding season produced only 50% as many 1-week-old ducklings as did controls. When dosage was continued into the second breeding season, the same hens produced 77% as many ducklings as controls, an improvement over the first year. In the second year, the reduced success was largely the result of duckling mortality, whereas in the first year, egg laying and hatching success also were affected. Mercury residues in eggs were somewhat lower in the second year.

Black ducks, given 3 ppm dietary dosage of methylmercury for 3 months before egg laying and allowed to nest and incubate their own eggs, hatched only 19 of the 46 (36%) eggs they incubated and only three ducklings survived to 3 weeks of age. In contrast, 65 of 89 (73%) of the control eggs hatched and 31 ducklings survived to 3 weeks. Most embryos died during the last week of incubation and most ducklings died between 2 and 7 days of age. Effects of the methylmercury were considerably more severe on black ducks than on mallards, paralleling the results of previous experiments with DDE.

Mercury highly persistent in ducks.—During spring and fall migration, ducks may stop for days or weeks to feed en route. Some of their stop-over areas are contaminated with mercury as a result of industrial effluent. The impact of these locally contaminated sites on wild waterfowl will depend in part, therefore, upon the accumulation of mercury during a short exposure and the length of time the residues are retained. In an experimental simulation of field exposure during migrational stopover, mallard drakes were exposed for 2 weeks to dietary mercury and given clean food thereafter. Even after 86 days of clean food, the ducks retained 46% of the mercury they had accumulated; and they retained 21% after 112 days. No measurable amount was lost between the 7th and 56th days, but the growth of new feathers after that time removed sufficient mercury to decrease body residues conspicuously.

Canvasback eggs contain low levels of organochlorines.—The canvasback duck population has declined and the causes are not known. The involvement of chemical pollutants in the problem was explored in 1973 by analysis of eggs from the principal breeding areas. Among 97 eggs sampled, only those from Manitoba contained elevated levels. DDE reached 12 ppm and PCB's 29 ppm in the extreme cases. In all, nine compounds were detected, including oxychlordane and hexachlorobenzene.

Lead in waterfowl assessed by wingbone analysis.—Lead accumulated by ducks as a result of picking up lead shot in the marshlands where they feed has been a longtime concern of the U.S. Fish and Wildlife Service. An evaluation of regional differences in lead contamination of waterfowl was undertaken in 1973-74 through analysis of wingbones of immature



Nuptial display of black-crowned night herons in the captive colony at Patuxent Wildlife Research Center. Herons and other wading birds that are at the top of estuarine and freshwater food chains can serve as indicators of environmental quality. (Photo by Luther Goldman)

mallards. Elevated levels were most common in birds collected from the Atlantic Flyway, particularly in the northeastern and Middle Atlantic States. The Central Flyway mallards had the lowest lead levels, and those from the Pacific and Mississippi Flyways were intermediate. Uptake of lead by bones is rapid, but the loss is slow. Levels in bone therefore reflect exposure to lead, but do not necessarily indicate acute poisoning.

Mercury declines in birds at Lake St. Clair.—In 1970, following the discovery of high mercury levels in the fish of Lake St. Clair, Mich., eggs of several species of wild birds from the St. Clair Flats Public Hunting Grounds were sampled for their mercury content. Soon thereafter, the chlor-alkali plants that were the source of the mercury discontinued release of their effluent into the lake and its tributaries. In 1973, the sampling was repeated. Residues had declined conspicuously. Mallard eggs collected in 1973 contained 0.05 ppm of mercury, down from a median of 0.57 ppm in 1970; mercury in eggs of black-crowned night herons declined from a median of 0.74 ppm to 0.36 ppm. Mercury in common tern eggs declined only slightly, from 1.5 ppm to 1.3 ppm. One egg was analyzed from each of 5 to 15 clutches for each species in each year.

Hérons show promise as biological indicators.

—Hérons and associated waders, which are at the top of both estuarine and freshwater food chains, are uniquely placed to serve as indicators of environmental quality. Ease of study and validity of generalizations are enhanced by colonial nesting, species differences in sensitivity to both chemical and nonchemical factors, and broad geographic distribution. Chemical contamination and eggshell thinning were examined first through field surveys of coastal and inland colonies from Florida to New Jersey. A total of 209 eggs of anhingas, ibises, and herons (other than black-crowned night herons) were collected for chemical and statistical study. Both species and geographic differences were apparent. New Jersey rated first in contamination by both DDE and PCB's. Great egrets topped the list of species.

Black-crowned night heron eggs were collected from 243 clutches at Gulf and Atlantic coastal localities from Louisiana to Massachusetts and in the Great Lakes area. Residues of dieldrin and DDE were highest in herons from more northern localities and consistently so

from areas where heron populations had declined. DDE was highest (61 ppm) in an egg from Long Island, N.Y.; dieldrin was highest (7.8 ppm) in a sample from Massachusetts; and PCB's were highest (102 ppm) in one from Rhode Island.

New pollutants in heron tissues: chlorinated styrenes and hexachlorobenzene.—Two great blue herons from Lake St. Clair contained residues of octachlorostyrene and related isomers, both confirmed by mass spectrometry. Reported concurrently from the Netherlands, the environmental source of these materials is not known.

Hexachlorobenzene, an industrial waste product and also a fungicide, was present in concentrations up to 1.4 ppm in four of five great blue herons from Lake St. Clair, in the only black-crowned night heron from the same area, and in one of six little blue herons from Mobile Bay.

Heavy metals assayed in Lake Erie herons.—Mercury concentrations averaged 3.31 ppm in livers of black-crowned night herons, higher than in great blue herons (1.88 ppm) or great egrets (2.73 ppm). Levels in nestlings were generally lower than in adults. Local differences were evident; birds from the West Sister Island heronry contained higher residues than those from Winous Point. Lead and cadmium concentrations generally were below the limits of detection. (This study was carried out under contract by the Ohio Cooperative Wildlife Research Unit.)

Use of captive mergansers in pollution experiments.—Heavy metals, particularly mercury, and organochlorines are generally higher in these fish-eating ducks than in other species of waterfowl. This fact suggested that the effects of pollution on the population should be explored and that mergansers might prove to be a useful experimental species in bridging the gap from aquatic to terrestrial food chains. In mid-June, eggs were obtained from the Seney National Wildlife Refuge in Michigan for exploration of methods of captive care. Newly hatched ducklings ate live food for a few days but soon adapted to duck mash and dog food. They will be held in different types of facilities for adaptation to experimental studies.

New Jersey marsh birds contain wide range of chemicals.—Marshland ecosystems of the Atlantic Coast include several species of rails and



A new experimental species for pollution evaluation at Patuxent Wildlife Research Center. A technician holds a hooded merganser reared in captivity. Wild mergansers carry heavy burdens of pollutants. (Photo by Luther Goldman)



Royal terns in a colony in Texas. Reproduction is apparently as successful here as it is in South Carolina. (Photo by Kirke A. King)

shorebirds as top-of-food-chain consumers. Population status and trends of most of them are poorly known and their response to pollutants is a matter for conjecture. Shell thickness has been measured for 8,489 eggs of eight species that were collected prior to the mid-1940's and for 776 modern eggs that have been collected for comparison and for residue analysis. Analyses have been completed for 38 eggs from New Jersey, and DDE and PCB's were detected in all of them. Species differences were evident: Eggs of herring gulls, laughing gulls, and least terns had highest residues (DDE, 1.32–9.54 ppm; PCB's, 1.95–10.73 ppm), and those of clapper rails and willets contained lower residues (DDE, 0.30–6.35 ppm; PCB's, 0.25–3.06 ppm). Other chemicals that were present in one or more of the eggs were: mirex, chlordane, nonachlor, oxychlordane, and heptachlor epoxide.

Royal tern prospers in South Carolina.—Continuing their success of 1970 and 1971, the colonies of royal terns on Marsh Island and Deveaux Bank in South Carolina fledged approximately 6,800 young from about 10,000 nests. Royal terns are a principal part of an ecological study of environmental pollutants in relation to South Carolina's estuarine birds. Others in the study include sandwich terns, black skimmers, least terns, gull-billed terns, laughing gulls, white ibis, and several species of herons.

Continued contamination in the Green Bay ecosystem.—Cracked and disappearing eggs still characterize herring gull nesting in Green Bay, Wis., the site of pioneering pollution research in 1966. Of 102 nests for which records could be made before heavy storms hit the area, only 32 had all eggs intact; 66 nests had one or more eggs with cracks or breaks in the shell. One or more eggs disappeared from 26 of the nests. Embryonic mortality in 75 eggs examined in a nearby area was 24%, not statistically different from the 30% mortality of 1966 and higher than records from the literature. (This study was carried out under contract by the University of Wisconsin.)

Environmental contaminants in Icelandic marine birds.—Fulmars breeding in Iceland in 1973 had DDE averaging 0.42 ppm in breast muscle; PCB's averaged 2.3 ppm. Corresponding averages for razor-billed auks were 0.11

ppm and 0.71 ppm. These values and the ratios of PCB to DDE are similar to those in British fulmars and auks. Such similar body burdens in birds breeding in nations of widely differing industrial capacity suggest a common source of organochlorine residues, the open North Atlantic Ocean. In contrast to DDE and PCB's, dieldrin concentrations in breast muscle were higher in auks (0.032 ppm to 0.014 ppm) than in fulmars. One hundred and six samples of 14 additional species, collected but not yet analyzed, will provide baseline data and an overview of contamination problems in these northern sites. (University of Wisconsin, contracted research.)

Alaskan seabird study.—In 1973 a survey of breeding colonies of Alaskan seabirds and the environmental pollutants in their eggs was begun as a joint program of the Northern Prairie and Patuxent Wildlife Research Centers. British workers have recommended the monitoring of seabirds as an indication of worldwide environmental contamination. Some of the species in Alaska are resident, others migratory, providing further opportunity for evaluating local conditions.

Songbird egg survey under way.—Thickness-index measurements were obtained from 9,429 museum eggs representing 11 species of songbirds. For comparison, eggs were collected in 1972–73 from 436 clutches in various localities in Eastern United States. Chemical analyses and shell thickness data will be used to help determine whether pesticides have had adverse effects on songbirds. This is the first widescale survey undertaken to measure contamination and potential effects of organochlorine chemicals on songbirds.

PCB thins coturnix quail eggshells.—Aroclor 1242, fed to coturnix at a dietary concentration of 10 ppm, resulted in eggs with shells 5.2% thinner than those of control birds. This parallels effects on chickens, but differs from effects on ducks, whose shells have not been thinned by this compound.

Residues in bald eagles, 1971–72.—Thirty-six eagles found dead or dying in 18 States all contained PCB's and DDE. Twenty-seven contained dieldrin, four at levels high enough to suggest death from dieldrin poisoning. Brains contained 4.0 to 7.8 ppm dieldrin; autopsy showed no injuries or gunshot wounds in these



Bald eagles fledged two young at Patuxent Wildlife Research Center in 1973, the first natural breeding of this species in captivity since 1938. A mirror above the nest permits observations without disturbance to the birds. (Photo by J. Maestrelli)

specimens. Chemicals detected less frequently included DDT, heptachlor epoxide, oxychlor-dane, cis-chlordane, cis-nonachlor, hexachloro-benzene, and mirex. Since 1964, cause of death and body burden of environmental chemicals have been investigated in 189 eagles found dead or dying and sent to the Patuxent Center. About 11% (20 eagles) had high dieldrin levels.

Captive bald eagles rear two young.—A pair of eagles carried through the entire task of brooding, feeding, and rearing two young in the spring of 1973. The eggs hatched in early April and the young fledged in late June. This is the first year since 1938 that captive bald eagles have been known to rear young.

Death of new-born bats in a Texas cave.—Female free-tailed bats fly north from Mexico each summer into southwestern United States

where they form aggregations numbering tens of millions in certain large caves. In recent years, some cave populations have declined dramatically. Speculation has centered on insecticides as the cause of the declines because this species is insectivorous; a single large colony may be capable of consuming up to 40 tons of insects nightly. Annually in each cave, tens of thousands of recently born bats lose their hold on the ceiling and fall into the guano on the floor where they are consumed within minutes by larval dermestid beetles. One hypothesis holds that elevated insecticide residues have increased the number of young that fall to the floor and die.

Comparison of 12 fallen young and 15 from the ceiling of Bracken Cave, Tex., showed similar amounts of chemical in both groups, but

higher, although still sublethal, concentrations in those that fell. DDE in brains did not exceed 5.5 ppm. The bats that fell were thin, accounting for the increased concentrations of residue, which occurs with weight loss. It was concluded that starvation, not DDE, caused the bats to fall.

DDE increases in young bats during nursing.—Young free-tailed bats in Bracken Cave, Tex., were born with a median level of 0.57 ppm (wet weight); their concentrations increased to 5.6 ppm during nursing, and concentrations in the female parents decreased. DDE in milk ranged up to 10 ppm, with a median value of 1.9 ppm. Although DDE crosses the placenta, much greater amounts are transferred to the young via the milk. Adult females appear to excrete approximately 8% of their DDE burden per day while nursing. Young females in their first breeding season have relatively high body burdens of DDE, derived from their mothers' milk, and passed again to their own offspring. Body burden of DDE gradually increases again as a result of food intake, but it reaches amounts greater than in yearlings only in the oldest females.

Birds lose PCB's slowly.—Grackles lost 50% of the PCB (Aroclor 1254) from their bodies within 1 month but no additional amounts by 4 months. At 8 months, however, 87% had been lost. In contrast, they lost 50% of the PCB from brains in 3 to 4 days, 79% in 1 month, but no more by 8 months.

Direct comparisons with DDE-dosed birds showed different patterns for the loss of this chemical. DDE residues were lost more slowly, only 16% in 1 month. DDE half-time was estimated to be about 6 months in contrast to 1 month for PCB.

Toxicities of the two chemicals were similar. When the dietary dosage was 1,500 ppm of DDE or of PCB, half of the DDE-dosed birds died in 7 days and half of the PCB-dosed birds died in 8 days.

PCB residues indicative of death.—Experiments with Aroclor 1254 showed lethal residues in the brains of four species of birds to be in the range of 349–763 ppm. Residues in brains of equally dosed survivors of the same species (starlings, cowbirds, grackles, red-winged blackbirds) did not exceed 301 ppm. Thus, brain residues of PCB's as well as of organo-

chlorines, proved to be diagnostic of death. Residues in livers were of limited diagnostic value. Livers of grackles that died contained 513 to 3,771 ppm of PCB. Livers of survivors usually had lower concentrations, but there was much overlapping. Birds sacrificed at the time of 50% mortality had 722 to 1,973 ppm. Residues in livers increased sharply with length of time both survivors and nonsurvivors were on dosage. Residues in bodies were higher in survivors than in birds that died, an anomaly that results from body storage of a chemical as a protective mechanism.

Lethal residues of dieldrin in ducklings.—Ducklings killed by dieldrin in standard toxicity tests contained dieldrin concentrations in brains that ranged from 1.49 to 22.81 ppm. Eight of the nine values were 5.33 ppm or above. The reading of 1.49 was lower than expected, paralleling some values obtained from field samples that have been difficult to interpret.



At Patuxent Wildlife Research Center, autopsy and histopathological study precedes chemical analysis in evaluation of effects of environmental pollutants. (Photo by Luther Goldman)



Administering a pesticide to a coturnix quail. The coturnix is a desirable experimental animal for studying the effects of pesticides on birds. (Photo by Luther Goldman)

Oxychlordan is toxic and persistent.—Oxychlordan, a metabolite of chlordane, proved to be nearly as toxic as dieldrin but considerably more persistent in studies with several species of blackbirds. Although oxychlordan is beginning to be identified in field-collected specimens, its potential for increase to harmful levels is not known.

In studies with the form of chlordane previously marketed, oxychlordan was the most persistent component. In work with the new chlordane, HCS-3260, there was more cumulative mortality than expected; large amounts of oxychlordan appeared and persisted. These results made it seem important to test oxychlordan alone. It should be noted, however, that oxychlordan is a metabolite and may never be found in the field in substantial amounts.

Half the adult female starlings used in toxicity tests died in 3.5 days when the dosage of the metabolite was 50 ppm in the diet. Half-times were longer when dosages were lower. At a dosage of 1.5 ppm, half the birds had died by 57 days and all but one had died by 155 days. Large amounts of oxychlordan accumulate in starlings, and relatively small residues are dangerous.

Phthalate-dosed mallards fail to accumulate residues.—Tissues of mallards fed 10 ppm dibutyl phthalate or 10 ppm diethylheptophthalate in the diet for 5 months did not contain more residues than those of control mallards. Phthalic ester plasticizers are widely used and have become ubiquitous at low levels, so that background contamination seriously interferes with low-level readings. Nevertheless, it is evident that mallards are able to eliminate most of the chemical in dietary dosages as high as 10 ppm.

Mercury in the diet of parents induces hyperactivity of offspring.—Concern that chemical pollutants might alter the normal behavior of wild species and thus affect their survival and reproductive success has often been expressed. As part of the evaluation of this problem, mallard ducks were fed low levels of mercury in their diets, and the behavior of their offspring was tested in an apparatus that measured the distances they ran from a frightening stimulus. In these tests, the young birds whose parents were fed 3 ppm mercury (as methylmercury-dicyandiamide), but who themselves had always received untreated feed, ran farther in a measured time period than did controls. This evidence of hyperactivity parallels effects that have been reported among mammals.

Toxicants affect adaptability of birds to stress.—The effects of toxicants on the ability of coturnix quail to adapt to stress were tested in the laboratory. The shaking motion in a laboratory shaker was the stressing agent, and elevation of plasma enzyme activity was the measure of stress. Birds fed clean food responded to rapid shaking by elevation of plasma enzymes, but if they were first exposed to several sessions of slow shaking, they adapted to the experience and the rapid shaking produced no effect. However, birds fed 12 weeks on diets containing 100 ppm of Aroclor 1254, 4 ppm of mercury (as methylmercury), or 160 ppm of malathion were unable to adapt fully; 30 to 50% of the plasma enzyme response to stress remained.

PCB's of lower chlorination least toxic to quail.—Aroclor 1248 (48% chlorination) was less toxic to coturnix quail than Aroclor 1254 or 1260 (54 and 60% chlorination) on an "as is" basis and also when dosages were adjusted to provide equal chlorine intake.

Parathion more toxic to birds fed methylmercury.—Dietary exposure to 4 ppm methylmercury for 18 weeks increased the toxicity of parathion to coturnix quail and correspondingly decreased the cholinesterase activity in brain and plasma. The dose of parathion that killed 50% of the birds not previously exposed to methylmercury was 5.9 mg/kg in contrast with 4.2 mg/kg for birds fed methylmercury.

Susceptibility of birds to dieldrin.—In a 5-day dietary dosage with ample food available, starlings proved most susceptible to dieldrin, bobwhite next, and coturnix quail least. When equivalent amounts (based on body weight) were given in a single dose, bobwhite were the most susceptible, coturnix next, and starlings least. Susceptibility in the field will be a function both of the amount of toxicant consumed and inherent susceptibility.

Species differences in DDE effects.—DDE fed at 10 ppm reduced shell thickness in eggs of mallards and ring doves, but not of pheasants. Calcium levels in the blood of the first two species also were reduced by DDE. Injection of parathyroid extract into the DDE-dosed mallards eliminated the calcium decrease. Pheasants, however, did not respond to injections of

parathyroid extract, nor did ring doves. Concentrations of estrogen in the blood of mallards increased as a result of DDE in the diet but decreased in the blood of pheasants. Bone calcium in DDE-fed mallards decreased, but did not change in DDE-fed pheasants. Parathyroid and probably estrogens appear to be directly involved in the effect of DDE on eggshell thinning. (This study was carried out under contract by the Ohio State University.)

Broad-spectrum chemical analysis improved and speeded.—New analytical procedures combined with automated equipment and mass spectrometric confirmations have extended sophisticated broad-spectrum analysis to all types of environmental samples. Species emphasized during the year were herons and related species, brown pelicans, bald eagles, insectivorous birds, and bats. All samples were analyzed for DDE, DDD, DDT, dieldrin, heptachlor epoxide, oxychlordane, cis-chlordane, cis-nonachlor, mirex, hexachlorobenzene, and polychlorinated biphenyls.

Residues reported on a "fat" basis need careful scrutiny.—Residues expressed on a fat (lipid) base should be compared with each other only if all phases of preservation and extraction are identical.

Rigorous extractions with a variety of polar and nonpolar solvents on formalin-preserved and frozen specimens yielded similar amounts of chemical but differed greatly in amounts of lipid. Parts per million expressed on a wet weight basis were similar, but would be greatly different on a lipid base.

Southeastern Fish Cultural Laboratory

Copper sulfate registration.—The application of copper sulfate as an algicide is the only use now approved under an exemption for tolerance. A thorough review of the literature on physical and chemical properties, mode of action, interactions, detoxification, efficacy, and toxicity showed that registration for such other proposed uses as a piscicide, molluscicide, or fish therapeutant is not justified.

Tolerance to thermal shock after exposure of fish to endrin.—Fish kills after rapid changes in environmental conditions, or during prolonged extremes, have been reported in populations having histories of pesticide exposure.



Spectrophotometer used to measure physiological effects of chemicals. Serum enzyme activities show tissue damage induced by organophosphates, organochlorines, or heavy metals. Enzyme effects, which are useful in both field and laboratory investigations, are being studied in many species. (Photo by John Maestrelli)

Pesticides are suspected of impairing the ability of fish to adapt and survive rapid environmental changes, but little documentation is available. Channel catfish fingerlings, adapted to 30° C and fed an endrin-contaminated diet (4.3 ppm, dry weight) for 28 days, were challenged with thermal shocks from 10 to 40° C. Both control and treated fish (whole body residue, 0.6 ppm) failed to adapt to 10 and 40° C but those exposed to endrin died much sooner than did the controls. Also, mortalities were higher in endrin-exposed fish challenged with 15° C, but not with 20, 24, and 30° C. At 35° C, 47% of the endrin-exposed catfish died within 72 hours, whereas only 7% of the controls died.

Pesticides in channel catfish.—Toxaphene is one of the more often encountered organochlorine pesticides in fish tissues, especially in the southeastern United States because of its intensive use there in agriculture. Residues greater than 30 ppm have been reported in channel catfish. Its biologic effects in fish other than its acute toxicity are largely unknown.

After 10 months, diets containing up to 32 ppm toxaphene produced whole-body residues as high as 12.4 ppm in sexually mature catfish held in ponds. Eggs from these adults contained 0.9 to 1.7 ppm and fry contained 1.1 to 1.4 ppm. No mortalities, deformed fry, or reproductive failures were attributable to toxaphene. The biologic half-life of the residue was estimated to be 26 days when contaminated fish were given uncontaminated food.

Dieldrin, another organochlorine insecticide often found in fish, was fed to immature channel catfish, and possible biologic effects, residue accumulation, and clearance were examined. Dieldrin residues reached a nearly constant value within 20 days and maintained it for 210 days. The residues had a biologic half-life of 10 days with the fish on uncontaminated food. Fish receiving 4 ppm dieldrin had about 18% less cumulative weight gain than controls during the 210-day period. No growth or mortality differences were observed in fish receiving 0.4 or 0.8 ppm dieldrin.

COASTAL AND ANADROMOUS FISH

Atlantic Salmon Investigations

In mid 1973, the Service expanded cooperative efforts with States and private organizations to restore Atlantic salmon in New England rivers. Significant advances have been made in producing salmon at national fish hatcheries, in assessing rivers for salmon restoration, in building fishways, and in studying salmon diseases. The Atlantic Salmon Investigations was established in June 1973 at the University of Maine, Orono. Its main objectives are to cooperate with Atlantic salmon interests in the United States and Canada in detecting needs for research in restoration of the species and to participate in this high priority research.

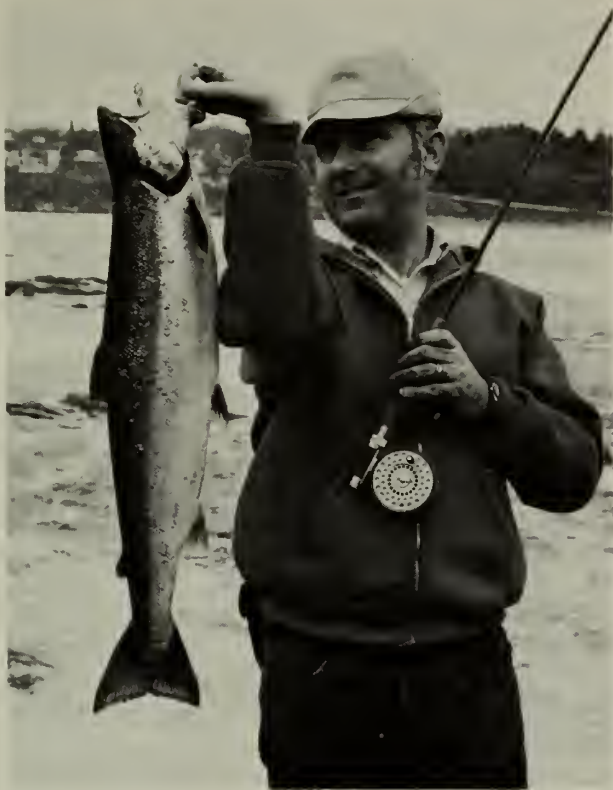
Several research contracts were awarded during the year. The preservation of salmon sperm is under study at the University of Maine in a project jointly funded by the Service and the International Atlantic Salmon Foundation. The Maine Cooperative Fishery Research Unit is determining potentials of the international St. Croix River for salmon restoration in cooperation with Canada's Department of Environment; conducting a salmon-oriented survey

of the Mattawamkeag River in cooperation with Maine Department of Inland Fisheries and Game; and investigating water quality and temperature relations in the Penobscot estuary in cooperation with Maine Atlantic Sea-Run Salmon Commission. Also at the University, a geneticist is characterizing salmon stocks in collaboration with the Maine Atlantic Sea-Run Salmon Commission and the North American Salmon Research Center, and a migration specialist is testing sonic tags for tracking migrating salmon smolts.

Eastern Fish Disease Laboratory

Health and disease of Atlantic salmon.—The Craig Brook National Fish Hatchery and the Eastern Fish Disease Laboratory have collaborated in studies of the Atlantic salmon. Tissues from adults, 1- and 2-year-old smolts, and all stages of sac fry, fry, and fingerlings have been collected, preserved, and prepared for sectioning. The purpose is to provide an illustrated guide to the normal microscopic features of salmon tissues.

Similar collaboration with the Tunisian Fish



James Fawcett of Orono, Maine, holds the first sea-run Atlantic salmon of the 1974 season from the famed Bangor Salmon Pool on the Penobscot River in Maine. A tag borne by the fish indicated that it was stocked as a hatchery-reared smolt into the Penobscot in May 1972. (Bangor Daily News photo)

Nutrition Laboratory has provided that Laboratory with microbiologically screened adults for sources of eggs. Pathological examination has also been carried out on fish from nutritional experiments. Atlantic salmon fry have proven to be susceptible to experimental infection with whirling disease and to the bacterium causing Hagerman redmouth disease.

As a guide to researchers and managers, world literature on Atlantic salmon disease has been searched. More than 150 references have been compiled and annotated in preparation for publication.

Fish Control Laboratory

Field trials of quinaldine sulfate:MS-222 (Finstill).—A field trial with this anesthetic mixture was completed at the Gulf Breeze Laboratory in Florida with two marine fishes.

Sailfin mollies and sheepshead minnows were anesthetized rapidly (in less than 4 minutes) with concentrations in ratios of 10:30 ppm or 20:60 ppm of QdSO₄:MS-222, held for 15 minutes in the anesthetic solution, and recovered within 6 minutes after being placed in fresh water. No mortalities were experienced and the efficacy of the anesthetic was described as "excellent."

Finstill was used at the same ratios and concentrations at the Pittsford National Fish Hatchery, Vermont, where pre-smolt Atlantic salmon, yearling rainbow trout, and eastern brook trout were tested for their response to the anesthetic. All fish were rendered unconscious in less than 3 minutes. Recovery time varied with exposure time and concentration. Fish that had been in the anesthetic solution for 5 minutes righted themselves within 13 minutes after being placed in fresh water, with no apparent adverse effects. Fish held in the solution for 15 minutes required up to 22 minutes for recovery, and 2 of 30 died.

The concentration of both quinaldine and MS-222 in plasma of fish following exposure increases rapidly. Concentrations of MS-222 in plasma of rainbow trout exposed to 100 ppm reached 38 ppm after 1 minute and 71.6 ppm after 35 minutes of exposure. Concentrations of quinaldine in plasma of rainbow trout exposed to 25 ppm quinaldine sulfate were 20 ppm after 1 minute and 31.2 ppm after 30 minutes of exposure.

Residues of quinaldine in fish muscle reached high levels (19.4 ppm) after exposure for 1 hour but no residues were detected after 24 hours of withdrawal.

Counteraction of fish control chemicals.—Data which demonstrate the absence or degradation of chemicals applied in the environment are required for registration. Unless the compounds degrade naturally in the environment, it becomes necessary to detoxify or remove the chemicals after they have fulfilled their intended purpose. Research in the area of counteraction during this year was directed toward exploratory testing.

Potassium permanganate (KMnO₄) is effective for detoxifying the fish toxicant antimycin in laboratory waters of pH 6.5 to 9.5. The toxicity of KMnO₄ to fish is influenced by temperature, water hardness, and pH. Susceptibility

of fish is increased by low temperature, hard water, or high pH.

Inasmuch as the toxicity of chlorine to fish precluded its use at 1 ppm for detoxifying antimycin, the effectiveness of 0.5 ppm chlorine was studied at pH's 7.5, 8.5, and 9.5, and 0.25 ppm of chlorine at pH 6.5. Chlorine was effective for detoxifying antimycin at pH's 6.5, 7.5, and 8.5, but not at pH 9.5.

Because Noxfish (5% rotenone) detoxifies more slowly than antimycin, detoxifiers would be helpful. Green sunfish were exposed to fresh and aged solutions of Noxfish containing 1.0 ppm of KMnO_4 to determine the half-life of Noxfish at four different pH's. The deactivation indices showed slight, nonuniform changes in the toxicity of Noxfish after aging periods of 10 to 50 minutes. Rotenone reacts quickly with the available KMnO_4 and the rate of subsequent detoxification decreases inversely to the KMnO_4 demand.

Activated carbon has been used to trap several fish control chemicals with varying degrees of success, depending upon the nature of the chemical, the pH of the water, and the temperature of the solution. Tests with aqueous solutions of TFM (3-trifluoromethyl-4-nitrophenol) showed that decreasing the temperature decreased the flow rate through the carbon filter but increased the trapping capacity. A decrease in pH from 8.5 to 6.5 increased the retention of TFM from 22.4 to 32.4 mg/g of carbon.

Activated carbon filtration effectively removed Furanace from aqueous solutions. Quinaldine sulfate (QdSO_4) and malachite green were also removed but formalin was only slightly adsorbed by the filter.

Southeastern Fish Cultural Laboratory

Protein requirements of striped bass.—Beyond satisfying the requirements for essential amino acids, the amount of protein, relative to the amounts of carbohydrates and lipids, influences the rate of food conversion, as well as the quality of flesh in fish growth. An optimal percentage is needed for the best economy in diet formulation and fish production. Test rations, formulated with 25 to 60% casein, were offered to young striped bass to simulate feeding artificial rations after natural forage in ponds is exhausted. Growth was linearly pro-

portional to percent protein up to 40%, and declined at 50% and greater. Appreciable mortality occurred in groups receiving 25 or 60% protein. The duration was too brief and difficulties with training striped bass to accept a bland, purified ration precluded a definitive evaluation of this study. But preliminary data were helpful in making adjustments for maintaining a large population of striped bass for other studies.

Tunison Laboratory of Fish Nutrition

Effect of water salinity on passage of food through the intestinal tract.—Aquarium studies at the Tunison Laboratory with a hatchery strain of rainbow trout and with steelhead cultured from eggs imported from Washington State were conducted with calcium-45 as a tracer. A direct relationship was found between the salinity of the aquarium water and the rate of passage and efficiency of utilization of labeled dietary calcium. Water made approximately isosmotic (but not isotonic) with fish blood serum, by adding potassium and sodium, caused a force-fed food mass to pass through the gastrointestinal tract two to four times faster than it did in (1) normal fresh water, (2) water made very hard with strontium and magnesium, or (3) water with both increased salinity and hardness. Although increasing the salinity alone stressed the fish, the stress could be partly offset by increasing the calcium in the feed. Possibly one or more of the alkaline ions can serve as a growth stimulant in saline water, especially if a calcium-enriched diet is available. Rainbow and steelhead trout were similarly influenced by these alterations in the mineral contents of the food and water.

Effects of incubation and rearing techniques on growth.—To replenish the declining Atlantic salmon stocks, more efficient cultural methods must be developed for rearing juvenile salmon to the smolt stage. Investigations during 1973 demonstrated that fry reared over an artificial substrate made of plastic column-packing material (2.5-cm saddle-shaped units) were 45% heavier, swam up earlier, and had lower mortalities, and fed much more actively than fry reared with conventional techniques. Parr reared from these larger fry maintained their superiority in mean weight for the year that they were observed.

In 1974, a large-scale experiment indicated that swim-up Atlantic salmon fry that had been reared in two types of plastic substrate were 40% heavier than those reared in hatching jars, troughs, or Roberson fry incubators. As in 1973, fry reared with the substrate material absorbed their yolk sacs faster (without the often observed abnormal constrictions) and began feeding sooner than fry reared by other methods. Fry reared with irregular substrates in several National fish hatcheries also displayed superior growth.

Evaluation of biochemical factors indicative of migratory behavior in Atlantic salmon.—The activity of a sodium-potassium-dependent adenosine triphosphatase (Na-K ATPase) in the gills of several species of migratory salmonids reflects their osmoregulatory status and can be used as an index of their readiness to be released from a hatchery environment.

The activity of Na-K ATPase in the gills of Atlantic salmon was highest near mid-May, which corresponds well with the time the fish are normally released from the hatchery at Craig Brook, Maine, to begin their seaward migration. The gill Na-K ATPase activity fluctuates in conjunction with other pre- and post-migratory behavior associated with the parr-smolt transformation.

Optimal levels of fat in diets for growth and survival.—Salmonids feeding on natural foods, such as insects, often receive a much higher percentage of fat in their diets and the ratios of fat to protein are different than in fish fed hatchery foods. In 1974 an experiment was begun to determine the optimum ratios of protein and fat in Atlantic salmon diets. Fat levels ranged from 13 to 27% of the dry ingredients, which included only herring meal, soybean oil, vitamins, and minerals. To date, growth in weight has been positively correlated with the level of fat in the diets.

Alternate sources of fat in salmonid diets.—Lipids that originate from marine fish fluctuate in availability and have become increasingly adulterated with industrial contaminants. Therefore a feeding trial was conducted on Atlantic salmon to determine if feeding less-contaminated, cheaper lipids of nonmarine origin, in a production-type diet, would provide sufficient polyunsaturated fatty acids considered essential for salmonids. Diets supplemented

with 4.5% of one of four oils—herring, soybean, raw linseed, or safflower—in addition to 2.2% of residual fat, were fed to 8.8-gram fish at 14° C. The calculated level of Omega-3 fatty acids (the predominant type in marine lipids) ranged from 0.1 to 2.1% of the dry diet. The lack of significant differences in growth, body composition, mortality, or histology of heart and liver among the fish fed the different lipids for 10 weeks suggests that nonmarine lipids can be substituted for marine lipids in salmonid diets without detrimental effects.

Application of findings from this and other basic nutrition research is leading to the development of new practical production diets that should prove to be excellent for starting and raising salmon.

Quantitative dietary selenium requirements of Atlantic salmon.—Selenium, extremely low in waters and food ingredients originating in the Eastern United States, is required for proper utilization of vitamin E by nonaquatic animals. Results conclusively show that juvenile Atlantic salmon reared in low-selenium water require trace amounts of dietary selenium which, in conjunction with vitamin E, prevented peroxidation of liver mitochondrial lipids, muscular degeneration, anemia, abnormal gall bladder emptying, low resistance to stress, and high mortality. Selenium is an integral part of fish glutathione peroxidase and enhances the antioxidative function of vitamin E within the fish.

Quantitative requirement for dietary phosphorus in Atlantic salmon.—Experiments were conducted to define the nutritional needs of young Atlantic salmon for phosphorus and trace minerals. It was shown that dietary phosphorus was required for optimum growth, feed utilization, and bone development. The supplemental inorganic phosphorus required was 0.6% in diets containing plant protein sources which provided a basal level of 0.7% phosphorus in the diet. Further study suggested that phosphorus contained in plant proteins was nutritionally less available than that contained in animal proteins or inorganic supplements. Nevertheless, the plant proteins had a high nutritional value when properly balanced and supplemented with inorganic phosphorus. Another study in progress suggests that manganese is an essential nutrient.

Unidentified growth factors associated with fish meal.—The sulfated amino acid taurine is under investigation as an unidentified growth factor for poultry. Fish meal, which is used extensively in hatchery production diets, is a rich source of taurine. Taurine and another possible growth factor, fermentation by-product, were tested for their growth promoting properties in hatchery-reared Atlantic salmon fingerlings.

Neither 0.1% taurine nor 0.25% fermentation by-product, nor a combination of the two had a significant effect on growth when added to a casein-based diet which was fortified with essential amino acids to resemble a fish protein concentrate in terms of the amino acid profile. Apparently, neither of these possible growth factors benefit fingerling Atlantic salmon, at least at levels shown to be beneficial to poultry.

Investigations on alternate sources of protein and amino acid supplementation.—The traditionally poor performance of proteins of plant origin in salmonid diets is related in part to deficiencies in their amino acid profile. However, their inferiority may be traceable also to other qualities which have not been as extensively investigated. Two versions of isolated soy protein, one containing 0.02% sodium and the other neutralized during preparation and containing 1.5% sodium, were tested as the sole source of protein in the diet of fingerling Atlantic salmon. Neither protein performed as well as the fish-protein-based control diet, and the method of preparation of the respective soy isolates had no effect on growth. An unexpected development was the occurrence of bilateral cataracts in 90% of the fish fed either of the soy isolates at 36% of the diet for 12 weeks. Recent information suggests that the essential amino acid threonine, although present in adequate amounts in plant proteins, may be unavailable to the digestive mechanism of an animal because of structural anomalies inherent in the protein.

When three levels of supplemental threonine were added to diets based on isolated soy protein as their sole protein source, growth of Atlantic salmon fingerlings was not benefited, and cataract formation was again evident.

Experiments, completed and in progress, were designed to better define the amino acids that are critical when alternate sources of protein are fed to Atlantic salmon. Studies sug-

gested that, besides meeting the minimum needs for the 10 essential amino acids, it may be necessary to understand potential complex interactions between amino acids that are detrimental to the optimum nutrition of salmon. However, a follow-up study of one such potential interaction showed that salmon were less susceptible than other animals to an excess of dietary lysine in relation to arginine. Salmon fed excess lysine had only a small increase in the enzyme that destroys body stores of arginine. As a result, depression in growth was of little consequence. Analyses showed that salmon have very low levels of this enzyme, thereby explaining the ability of the fish to tolerate considerable excesses of lysine. This tolerance may be important in future formulation of diets containing new sources of proteins.

Western Fish Disease Laboratory

Comparative hematopathological study of infectious hematopoietic necrosis (IHN), viral hemorrhagic septicemia (VHS), and infectious pancreatic necrosis (IPN).—A rapid presumptive field test for the diagnosis of IHN has been developed in cooperation with investigators from Denmark, France, and Italy. Examination of stained peripheral blood smears and stained imprints of kidney tissue allow us to detect pathological changes in red and white cells of infected fish on a semiquantitative basis.

Although the test will not differentiate between IHN and VHS, this is of no concern in the United States at present because VHS has not yet been reported here.

Virological as well as histological examinations continue to be required for a definitive diagnosis.

Vibrio vaccine trials.—In cooperation with the Washington Department of Game, groups of steelheads were immunized concurrently in the laboratory and field with a vaccine made from *Vibrio anguillarum* isolated from fish from the mid-Puget Sound area, Manchester, Wash. Protection was demonstrated in the vaccinated fish held in the laboratory by the use of LD₅₀ (the amount of a substance that kills 50% of the animals treated) tests, and in the field by using natural exposure in nets suspended in areas where the pathogen is endemic. The fish immunized with the Manchester vibrio isolate also showed protection when challenged against



Vibrio disease is prevented in steelhead trout by injection of vaccine. (Photo by A. J. Ross)

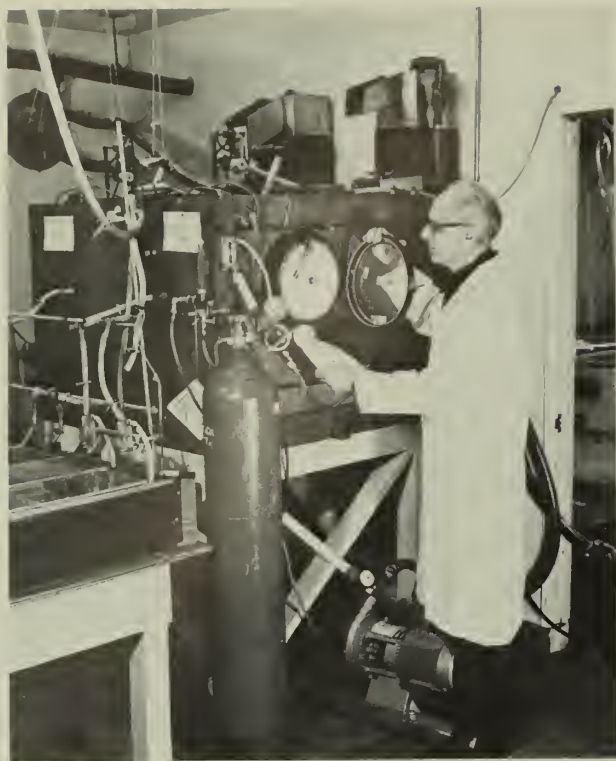
other vibrio pathogens isolated from different areas of Puget Sound, showing that there is cross-protection among at least some of the different isolates. The results of these protection tests will be correlated with the numbers of survivors from the immunized and control groups of steelheads when they return from the sea several years from now.

Nitrogen gas studies.—An excess of nitrogen gas in the water can cause a situation in fish that may be likened to the bends in humans. Since the construction of power dams on the Columbia and Snake rivers the condition has become critical. We have shown that gas bubble disease is related to the temperature of the water, the total gas pressure of the water, the stage of development of the fish, and the species of fish involved.

Also it was shown that maintaining a 119% total gas pressure and varying the oxygen: nitrogen ratio from 50% O₂:138% N₂ to 229% O₂:90% N₂ caused a decrease in morbidity.

Contribution to the literature on fish diseases.—A textbook "Environmental factors in fish diseases" is being prepared for the series, "Diseases of fishes," being edited by S. F. Snieszko and H. R. Axelrod.

Physiological effects of copper sulfate (CuSO₄) and Cutrine treatments on juvenile coho salmon.—Copper sulfate can be a useful therapeutant for fish disease control but it has only a small margin of safety in soft water. In this study, the toxic side effects of CuSO₄ treatments of juvenile coho salmon were compared with those caused by chelated copper (Cutrine). Both chemicals caused significant blood chem-



Apparatus for subjecting fish to flowing water with a constant temperature and a specific oxygen and nitrogen content. (Photo by R. R. Rucker)

istry disturbances; about 2 weeks were required for complete recovery from a standard 1-hour treatment. Although the acute toxicity of Cutrine was less, its sublethal treatment side effects were not significantly milder than those caused by CuSO_4 treatments.

Handling and crowding stress.—The stress of high population densities can predispose anadromous fish to infectious diseases or acute mortality, especially during smoltification. Coho salmon were acclimated to an initial population density of 0.5 pound per cubic foot and then transferred to population densities (pounds per cubic foot) of 1, 2, 4, 6, and 12 and sampled at 0, 1, 2, 4, 8, 12, 16, and 20 days.

In nonsmolting coho salmon, hyperglycemia occurred almost immediately following transfer to population densities of 6 or 12 pounds per cubic foot. At population densities of 4 pounds per cubic foot, onset of hyperglycemia was delayed by about 1 day. There was essentially no hyperglycemia at the lower fish densities tested. All three affected groups of fish

adapted physiologically to the higher population densities within 3 to 4 days.

The smolting coho salmon were much more sensitive, as expected, and a significant hypochloremia as well as hyperglycemia occurred upon transfer to a population density of 2 pounds per cubic foot. Transfer to population densities of 4.6 or 12 pounds per cubic foot was extremely stressful, and heavy mortalities followed the onset of blood electrolyte imbalance. If smolting fish must be handled, keeping the population density below 2 pounds per cubic foot will help minimize adverse physiological effects.

Western Fish Nutrition Laboratory

Migration and saltwater adaptation of salmonids.—One of the most critical periods in the life cycle of juvenile salmonids is the first month after release from the hatchery. Perils encountered during seaward migration and initial contact with the ocean environment often take a heavy toll, especially if the young fish are not adequately prepared physiologically for these experiences.

To study the physiological processes involved in migration and saltwater adaptation, the Western Fish Nutrition Laboratory established a variability salinity field station near Port Townsend, Wash. The nutritional and physiological requirements of young salmon and steelheads to make the transition from a freshwater to a seawater environment will be investigated. We have now initiated tests to standardize conversion procedures and to screen for disease-free fish.

Cooperation with the nearby Chimacum High School fisheries class in the evaluation and utilization of Chimacum Creek, a small creek about 10 miles from the field station, has resulted in some initial studies on steelheads. During February, March, and April in both 1973 and 1974, about 2,000 steelhead smolts were imprinted in water from the creek for 10 days, then tagged, weighed, measured, and released into the stream. These fish had been subjected to accelerated photoperiods to induce early smolting, which allowed early releases in February. A weir will be constructed to permit an accurate counting of all adult steelheads returning to the stream. It is hoped that this study

will provide information on the survival of fish released in February compared with that of fish released during the normal March–April period.

Dietary fat requirements of steelhead trout.

—Most dietary fat in animals is used as an energy source. However, certain fats are important in the formation of cell walls, enzymes, and other cellular components. Studies indicate that steelhead trout have a dietary requirement for either the 22 carbon hexaunsaturate, docosa-hexanoic acid commonly found in fish, or the 18 carbon triunsaturate vegetable-derived linolenic acid. Steelheads can synthesize the latter fat from the former, which appears to have a function other than that of an energy source. There was a surprising lack of linolenic acid in the heart and liver, even though it was the predominant fat in the diet. A large amount of docosa-hexanoic acid was present even though none was fed when the fish were given a diet containing linolenic acid. However, when diunsaturated linoleic acid was fed, there was no conversion to docosa-hexanoic acid, and the fish grew poorly.

During starvation, docosa-hexanoic acid seems to be depleted much faster than any other fatty acid. Comparison of three groups of fish reared at about 6, 10, and 15° C showed that after 2 months of starvation, more than 10 times more fish died in the 6° C group than in the groups held at the higher temperatures. This observation suggests that the fish reared in cold water were much more poorly prepared for starvation stress than fish in the groups from warmer water. Whether docosa-hexanoic acid plays a role in protecting fish against this stress is yet to be determined.

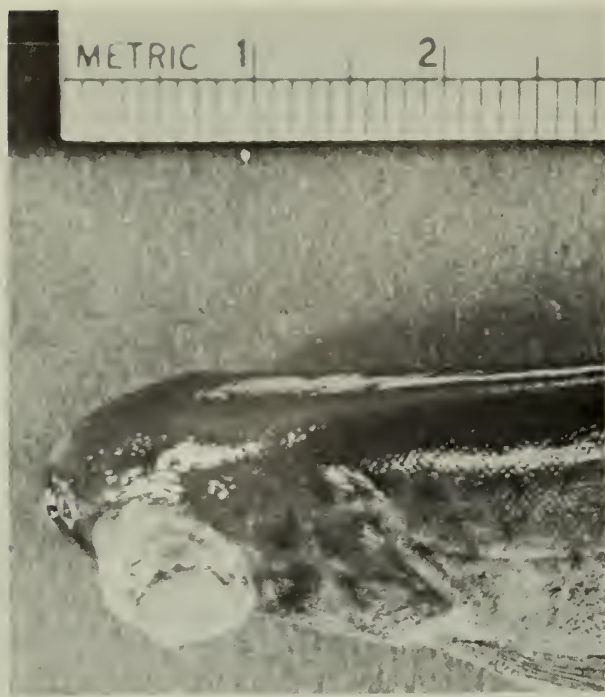
Unsaturated fats and the metabolism of toxins.—Polyunsaturated fatty acids markedly affect the manner in which an aromatic amine, used as a sample toxin, is metabolized by blood from salmonids. The reaction studied is mediated by peroxidase and is depressed by catalase, demonstrating that hydrogen peroxide is used to facilitate oxidation of the aromatic amine toxin, benzidine. The manner in which this toxin is metabolized in fish blood was related to the concentration of ascorbic acid, vitamin E, and vitamin A. These vitamins and catalase all appear to function in the same manner in the oxidation of this foreign compound.

Large differences were found in blood from coho salmon and steelhead trout in this peroxidatic oxidation of benzidine. Since these two species are known to be very different in their resistance to toxins, it will be important to learn whether this difference in resistance is related to, and possibly a result of, species-dependent characteristics of this reaction.

Squoxin review.—As a participating laboratory in the Fish and Wildlife Service's effort to assemble data for FDA (Food and Drug Administration) and EPA (Environmental Protection Agency) leading to clearance of 25 high-priority chemicals used in fish culture and control of undesirable species, a thorough literature review was prepared on Squoxin, an agent for the eradication of squawfish from waters suitable as salmonid habitat.

Normal ranges in blood chemistries for coho salmon.—Research efforts were concentrated on the establishment of normal ranges in blood chemistries (blood urea nitrogen, serum albumin, total lipid, cholesterol, total protein, and hemoglobin) considered diagnostic of health, malnutrition, and diseased states of salmonids. Liver glycogen levels were also determined. Individual fish from four groups of coho salmon fed two diets and held at 5 and 10° C were sampled periodically from the 6th to 17th month after hatching. Significant changes in total protein, urea nitrogen, and liver glycogen were correlated with age, diet, and temperature. We are statistically analyzing other blood characteristics to determine their usefulness as health diagnostic tests in production hatcheries and field surveys.

Dietary carbohydrates.—A shortage in supply coupled with a great increase in cost of fish meal protein has prompted a search for alternate sources of dietary protein, as well as means of effectively reducing quantitative protein requirements of salmonids. Dietary carbohydrates were investigated as energy sources to reduce the fish's physiological demands for protein. Test diets were formulated which contained only 36% of dry weight protein rather than the usual 50%, and in which the 20% starch (white dextrin) was replaced by equal weights of either simple, more readily digestible sugars, glucose, fructose, or galactose, or the trihydric alcohol glycerol.



Pop-eye, resulting from inflammatory response to bacterial kidney disease organisms in the post-orbital region of yearling spring chinook salmon.

Rainbow trout fry maintained at 5° C on the four test diets showed no significant difference in growth rate over 14 weeks when compared with fry fed a diet incorporating 50% protein and 20% starch. On the other hand, coho salmon maintained for 16 weeks at 15° C on the four test diets exhibited only 46 to 60% of the growth characteristic of fish on the high protein diet. Apparently temperature may have a profound effect on the dietary protein requirements of salmonids or the utilization of carbohydrates, or both.

Kidney disease organism located behind the eye.—Bacterial kidney disease is common in salmonid fishes. The organism generally first attacks the kidney and eventually results in death. In 1974, however, the organism was found immediately behind the eye in yearling spring chinook salmon at two hatcheries in the area. The bacteria apparently gain entry through the eye opening, possibly due to an abrasion or other eye injury that breaks the protective membranes. The bacteria are temporarily isolated there by the fish, resulting in a large inflammatory, tissue response. The bac-

teria, however, eventually gain entry to the blood stream, resulting in the destruction of other organs, and eventual death. The chronic character of these lesions indicates either that the organism is of low virulence or that the fish is highly effective in isolating the bacteria on a short-term basis. This finding is apparently the first report of kidney disease in which the eye is the initial target tissue.

Fungus outbreak in cold water.—The fungus *Phoma herbarum* was highly virulent in coho salmon fry in a 5° C water supply. One outbreak of the disease eliminated entire stocks of coho salmon held at this temperature, whereas no mortalities were observed in fish from the same stock held at 10° C or above. The outbreak of this disease indicates either an ineffective immune system in coho salmon at low temperatures or that the fungus is psychophilic.

Heat-stable vitamin C for fish diets.—Ascorbate-2-sulfate, a heat-stable form of vitamin C, has been used in experiments with rainbow trout and coho salmon, to test for vitamin C activity. This derivative is apparently a suitable source of vitamin C activity. No difference from controls was observed in tissues of test animals maintained on ascorbate-2-sulfate. No L-gulonolactone oxidase activity has been detected in liver or kidney tissue from rainbow trout fed diets low in vitamin C, indicating the absence of this ascorbate-synthesizing system. However, rainbow trout fed to 40 g in weight on diets containing 100 mg of vitamin C per 100 g diet stored enough of the vitamin to survive for 1 year on a vitamin C-deficient diet, without appearance of vitamin C deficiency.

Biochemical determination of salmon smolts.—Anadromous fish such as Pacific salmon and steelhead trout undergo a metamorphic change (parr-smolt transformation) prior to seaward migration as juveniles. The most noticeable physical changes are: (1) a loss of dark parr marks on the sides with an accompanying increase in silvery color, and (2) a decrease in the ratio of weight to length. In addition to these physical changes, biochemical changes also occur, making it possible to differentiate chemically between a parr and a smolt. During the past several years efforts have been concentrated on one of these biochemical indicators—the sodium, potassium-stimulated ATPase activity in the gills. This enzyme is important in



Smolt (upper fish of each pair) and parr salmon. Note the silvery coloration and light-colored fins of the smolt.

the regulation of blood levels of sodium and potassium and its activity increases as the fish transforms into smolt in preparation for a saltwater environment.

Recent experiments have shown that coho salmon reared at a production hatchery can be

induced to undergo parr-smolt transformation early by accelerating the photoperiod schedule. Such treatment could result in early releases to avoid the problem of nitrogen supersaturation in the Columbia River, and also to reduce labor and feed costs. Parr-smolt transformation

in coho salmon was accelerated by rearing the fish in warm water (15° C). However, if left in warm water longer than about 3 weeks after becoming smolts, gill sodium, potassium ATPase activity became reduced, suggesting a loss of smolt condition. If the fish which had become smolts early in warm water were transferred

to cold water (about 5.5° C) after ATPase activity had become elevated, however, the activity remained high for several months. This use of temperature and photoperiod to control parr-smolt transformation in salmonids allows greater control of management problems in rearing these fish for maintenance of runs.

ENDANGERED SPECIES

Cui-ui Lake Sucker Project

A facility for holding sexually mature cui-ui adults, incubating 1.5 million eggs at one time, and rearing the fry to swim-up size has been constructed on Hardscrabble Creek (in Nevada) on land leased from the Pyramid Lake Paiute Tribe. A total of 1.6 million swim-up fry were released in the lake in 1973 and 1.9 million in 1974.

Several agencies and groups that have cooperated in various project activities include the Nevada State Fish and Game Department; the Pyramid Lake Paiute Indian Tribe; the Desert Research Institute, University of Nevada, Reno; the Division of Fishery Services

Unit, Reno; and the Lahontan National Fish Hatchery, Gardnerville, Nev.

Training of tribal members to assume the fish-cultural phase of the program is progressing well and the Division of Cultural Methods Research will be able to withdraw, as planned, by the end of fiscal year 1975.

A cold spring season apparently delayed the spawning run in 1974; the first adults were caught on 1 May, as compared with 3 April in 1973. A total of 249 adults were collected and taken to the hatchery for subsequent spawning. Of these, only 24% were males. Males average nearly a pound less than females, and many probably escaped the 6-inch mesh gill nets used



Injection of 0.02 g of pituitary gland suspended in 1.0 ml of normal saline solution causes most cui-ui females to spawn within 48 hours. Males seem to respond better after injection with 1250 units of mammalian chorionic gonadotropin.

in making the collections. The total of 2.94 million eggs spawned yielded 1.9 million fry (65% hatch). The inadequate number of males collected probably contributed to the relatively poor hatching success.

Construction of a concrete water control structure in Hardscrabble Creek was completed in October 1973. This structure has enabled us to avoid the extremely low water flows that were experienced in spring 1973.

A 6-inch well was drilled to a depth of 400 feet at the Hardscrabble site in May 1974. The well driller estimated a flow of 25 gallons per minute from this well under continuous pumping. Although this amount is less than we had hoped for, it will meet nearly all of our needs in case of complete stream stoppage.

The number of egg jars within the hatchery was increased from 20 to 30, giving a capacity of about 1.5 million eggs at one time.

Twelve days of fishing with a fyke net proved fruitless for capturing cui-ui within the lake or in the Truckee River, although other species were caught. High flows in the river made fishing with this net very difficult and the value of this type of netting gear remains in doubt.

A number of fertilized eggs from Tahoe suckers were transported to the Hardscrabble Hatchery in July 1973 for incubation, rearing, and collection of serial specimens. Larval Tahoe suckers and cui-ui were sent to the Alabama Cooperative Fishery Research Unit for a study of characteristics which will permit identification and separation of larvae of the two species.

Preliminary work on incubating cui-ui eggs in Pyramid Lake water showed that they will not absorb lake water and therefore do not water-harden properly nor increase in size. A malfunction of the pump supplying water to these eggs prevented carrying them to the expected hatching date; however, this observation strongly suggests that within-lake spawning success of the cui-ui is restricted to areas of freshwater inflow.

An oxbow pond on the Truckee River near Nixon was treated with rotenone with the cooperation of Fishery Services, Reno Unit. After detoxification it will be stocked with juvenile cui-ui for evaluation of rearing potential.

Poor results were obtained in feeding trials with juvenile cui-ui at the Lahontan National Fish Hatchery research facility. Conventional

trout rearing techniques at three water temperatures (about 12, 18, and 24°C), which included the feeding of dry trout food and a tropical fish food, resulted in poor growth, a high mortality, and skeletal deformities in many of the survivors. The development of sufficient capacity at the Hardscrabble Unit for holding adults, incubating eggs, and producing swim-up fry, in addition to the relative ease of operation, led to the decision to terminate activities at the Lahontan Research Unit. The building is being used for storage but could quickly be placed into operation if unforeseen circumstances at the Hardscrabble Hatchery (e.g., inadequate water flow) dictated this action.

Great Lakes Fishery Laboratory

Endangered fishes of the Great Lakes.—Of the seven endemic species of Great Lakes ciscoes (primarily deepwater members of the whitefish family commonly known as "chubs" by commercial fishermen), two—the deepwater cisco and the longjaw cisco—are almost certainly extinct. The blackfin cisco is extinct or nearly so; in the latter case, its range is restricted to Lake Superior. The range of several other species of ciscoes has been greatly reduced. Only the bloater is still common, but its numbers are declining throughout the Great Lakes.

As part of the continuing study of this group of disappearing Great Lakes species, more than 1,000 specimens of ciscoes were collected for identification from lakes Huron, Michigan, and Superior, and (for comparison) from Lake Nipigon, Canada. Although not all specimens have been identified, most appear to be lake herring, bloaters, and shortnose ciscoes. The abundant Lake Nipigon ciscoes are unique. Commercial fishing, pollution, and invasion of smelt and alewives—all of which are factors blamed for the decline of ciscoes of all species in the Great Lakes—are not factors in Lake Nipigon, where the blackfin cisco is still abundant.

Although attempts to find blue pike in lakes Erie and Ontario in recent years have failed and the species is believed to be extinct there, blue pike and hybrids (blue pike \times walleyes) may still be present in Lake Nipissing, a Canadian tributary of Lake Huron.



Young black-footed ferrets at play. (Photo by Donald K. Fortenberry)

National Fish and Wildlife Laboratory

Information provided to the Office of Endangered Species and International Activities included effects of land use practices on mammal populations; data on the status of populations and habitat requirements of species of birds, kangaroo rats, bats, and carnivores for the planning of recovery programs; information on the status of primates; and data on the status of populations of some species of bats. Applications for permits to import endangered species were reviewed, and appendixes for the Convention of International Trade in Endangered Species of Wild Fauna and Flora and the new Endangered Species Act were drafted. Information for habitat management of endangered species was provided to the Bureau of Land Management.

Patuxent Wildlife Research Center

Wolves censused and tracked in Minnesota.—Several years' research, during which over 100 wolves were radio-tagged, indicates that about 400 wolves were on the 4,200-square-mile Superior National Forest of Minnesota in the winter of 1972–73. A male wolf dispersing from this population was radio-tracked for a direct distance of 130 miles during 3-1/2 months; it covered a minimum of 320 miles (and an estimated 700 miles) during the trek. Another wolf has worn an operating radio collar for over 2 years and has been located at least once each week during that period. In addition to "bugging" the wolves themselves, researchers have

been fitting the dens with microphones that transmit howling to a continuously running tape recorder 15 miles away; some 80 howling sessions have been recorded in this way.

A pack of four radio-tagged eastern timber wolves from northern Minnesota, live-trapped in late December 1973 and January 1974 and held in a pen near International Falls, were transported by aircraft to the Huron Mountain area of northern Michigan. This transplanting study is a program funded by Northern Michigan University, the National Audubon Society, and the Huron Mountain Wildlife Foundation, in cooperation with the Michigan and Minnesota Departments of Natural Resources and the U.S. Fish and Wildlife Service. The wolves were weighed, measured, ear-tagged, equipped with radio collars, sampled for blood, vaccinated against various diseases, and given antibiotic protection against infection. They were held for a week under close observation in a large pen where they subsisted on road-killed deer provided them until released at dusk on 12 March 1974. Although there were some initial exploratory movements, they eventually settled into a smaller territory of about 250 square miles not far from where they were released. No conflict with livestock or other domestic animals seems to have occurred, and evidence of resumed feeding on deer suggests that they are adapting successfully to their new location.

Black-footed ferret studies.—Reports of ferret sightings continue to be received from several States in the Great Plains region, sug-

gesting the existence of remnant populations. Good evidence of ferrets was found this year in prairie dog towns in North Dakota, Nebraska, Kansas, Oklahoma, and Colorado. Several State and Federal agencies are cooperating in an effort to locate and map prairie dog distribution.

Principal efforts in South Dakota are directed toward determining ferret mobility and identifying home range and spatial requirements. Three black-footed ferrets were located during the summer in prairie dog towns where the species had been seen in previous years. One male and one female ferret, advanced in years as evidenced by peg-like canine teeth, were live-trapped and transferred to Patuxent in the fall of 1973. Prior to transfer, the animals were held in quarantine where they received a series of vaccinations against canine distemper. A total of five individuals, three males and two females, are now at Patuxent; studies are under way on their behavior, reproductive biology, physiological norms, and nutritional requirements.

Aleutian Canada Geese released on Agattu Island, Alaska.—During the summer of 1973, Patuxent researchers reared 60 goslings. This number is almost triple the annual average for

the past 7 years during which 152 Aleutian Canada geese have been produced. In anticipation of reduced productivity of the original stock obtained from Buldir Island in 1963, 17 goslings from the island were added to the Patuxent breeding flock in 1972.

Forty-one 2- and 3-year-old geese were shipped by air to Attu Island in the western Aleutians on 18 March 1974, where they were held until weather permitted their transfer to Agattu Island for release early in May. Four pairs of the captive-reared geese are known to have nested in the vicinity of the release site on Aga Cove. A family of wild Aleutian Canada geese will be moved from Buldir Island to Agattu during the early summer in the hope that they will provide migrational guidance to the Patuxent stock during the fall migration. Close daily observation of the flock will be maintained throughout the summer by Service biologists.

Foxes, previously believed to have been eliminated on Agattu, were found in the release area. Local control may have helped prevent losses of birds to date.

California condor status continues critical.—Condor productivity continued to be critically low despite increased protection of nesting



A pair of adult Andean condors with chick about 8 months old and 20 pounds in weight. In the wild, the young remain with the parents about 17 months. (Photo by Ray Erickson)



Florida everglade kite nest on artificial structure. The nest containing young, originally in cattails and jeopardized by rising water levels on Lake Okeechobee, was moved to the structure and care of the young was continued by the parents. (Photo by Paul W. Sykes, Jr.)

areas and first attempts at augmenting local food supplies. Only two young are known to have been reared in 1972, and the 1973 figure may be lower. In addition, as many as three condors are suspected of having died during 1972-73; this is considered to be more than usual. Efforts to protect birds and improve nesting conditions continue. Estimates of the number of California condors are still imprecise, and efforts are being made to improve survey methods. Two attempts were made in 1973 to attract condors to feeding stations where they could be counted. More than 20 condors were observed, but the technique does not appear to have the precision necessary for measuring changes in population size.

Andean condor hatched and reared.—The breeding pair of Andean condors at the Patuxent Wildlife Research Center laid a single egg on 25 March. The egg was “well pipped” on the 55th day but the shell was crushed and the still active female chick had to be helped from the drying shell membrane on the 58th

day, 2 days after normal hatching should have occurred.

Except for the naked head and feet, the chick was covered with a long whitish down, which was replaced with dark gray down within 3 weeks. The chick grew rapidly and weight increased at an average of almost 1 pound per week until it reached 19 pounds. The first flight was observed when the chick was 6 months old, and within 2 more weeks it was flying well within the confines of the pen.

Laysan ducks decline in numbers.—For unknown reasons, the population of Laysan ducks has dropped to the lowest level known since 1936. Only 25 birds were located in the highest of several counts at sunrise and sunset. Most of the 25 appeared to be young birds, since only one individual in full adult plumage was seen. Because of their crepuscular and nocturnal habits, Laysan ducks have always been difficult to locate and count. Rough correlations appear to exist between water level in the lagoon on Laysan Island and the number of ducks. The low populations may be related to the exceptionally low water levels this year.

Everglade kite populations and habitats assessed.—Sixty-five Florida everglade kites were counted in 1973 in the ninth annual census. Counts in previous censuses have ranged from 44 to 120, with a mean of 82. As many as 21 birds used the experimental kite management area in Loxahatchee National Wildlife Refuge between 2 and 4 May. Nesting activity was greater this year than in any of the last 5 years; 32 nesting attempts were noted, 26 at Lake Okeechobee, and 6 on the headwaters of the St. Johns River. For the third consecutive year no nesting was noted in the Everglades. Of the 32 nests, 10 (31%) were successful, fledging 25 young. This is an average of 2.5 young per successful nest or 0.8 young for all nests.

An aerial survey of freshwater marsh habitat in the southern two-thirds of the Florida peninsula showed that all such habitat is marginal for everglade kites on a long-term basis. Survival of the kites is believed to depend upon water level control and management of kite-occupied marshes.

Everglade kite nests successfully moved to artificial structures.—Four nests built in precarious positions in cattails and judged likely

to settle, to be blown down by high winds, or to be overturned by heavy rains were moved to artificial basketlike structures. In all four transfers, the parent birds accepted and occupied the artificial structures. Two of the four nests were successful, fledging five young.

Snail kites produce chicks.—South American snail kites at Patuxent are being used as experimental prototypes for their close relative, the Florida everglade kite. Thirty-four fertile kite eggs were produced in 1973 and 19 hatched. The average length of life for the kite chicks, however, was only 4 days; no difference was detected between seven cared for by the parents and the remainder which were raised by hand. Different diet formulas or treatments were tried on the hand-reared chicks; sodium selenite was added to the diets of two chicks, liver injections were given to four chicks, and one chick received a hypo-allergenic diet. *Escherichia coli* detected in the livers of dead chicks may have been responsible for the deaths, although occurrence of this bacterium may not have been the primary obstacle to survival of the kite chicks.

Drought and reintroduction of masked bobwhites.—Masked bobwhites in Sonora, Mexico, were subjected to a third straight year of severe drought (the rainfall in 1973 was the lowest in 40 years), and continued excessive livestock use of forage devastated the land. The high bobwhite call counts of 1970, compared with those of 1973, suggest a 70% population reduction, making the present situation extremely critical for the small remnant population. On a leased study area of 1,840 acres in the Altar Valley, complete control of post-release management practices will be maintained for 5 to 7 years.

In April 1973, 199 quail produced at Patuxent were released at two locations, and 275 others were released at another site in July. Those released in July immediately paired, dispersed, and began courtship; calling by males was widespread and vociferous. However, mid- and late-summer rainfall failed to provide sufficiently high humidity to trigger reproduction, and the birds stopped calling and reformed into coveys by 24 August. Since the same conditions have now existed for 3 years (1971–73), a valid test of survival and reproduction of masked bobwhites in southern Arizona has not been possible. With improved climatic conditions,



A census of Yuma clapper rails, using magnetically-taped calls, resulted in locating 910 birds along the lower Colorado River in 1973. (Photo by Roy E. Tomlinson)

reestablishment feasibility may be evaluated more accurately.

Releases of 370 masked bobwhites shipped to Arizona from Patuxent on 8 April 1974 and held in newly constructed conditioning enclosures are being made periodically in groups of varying size in order to determine the best time from the standpoints of survival and reproduction. Disadvantages of the earliest releases included increased vulnerability to predation, primarily by coyotes, and greater dependence upon supplementary feed and supplied water. Studies were also begun with substitution of masked bobwhite eggs in the clutches of recently captured, incubating scaled quail which will later be released with their foster broods. Training which the young bobwhites are expected to receive from the adult wild scaled quail may enhance prospects of their survival to maturity.

Wild whooping crane population declines.—After reaching a total of 59 in the fall of 1971, the whooper population dropped back to 51 in 1972 and to 48 in 1973. It is believed that most of the mortality was experienced by the non-breeding component of the population because similar past declines resulted in no appreciable reduction in the productivity of the remaining flock. Whoopers at Patuxent total 17, and there are 2 at the Audubon Park Zoo in New Orleans and 1 at the San Antonio Zoo in Texas, yielding a total of 68 birds of this species as of the end of calendar year 1973.

For the 5th year, whooping crane eggs were obtained in Wood Buffalo National Park where 14 nests with two eggs and 1 with one egg were found. One nest with two eggs was left for photography and behavioral study. Of 13 eggs removed from as many two-egg clutches, 2 were nonviable when taken and 9 of the remaining 11 eggs hatched at Patuxent. Four chicks from the nine hatched eggs died of drug-resistant bacterial infections during the first 2 weeks and five chicks survived, bringing the total whooper population at Patuxent to 22 as of the end of June 1974.

Whooping crane behavioral research initiated at Patuxent.—During spring and summer 1973, nine whooping cranes reared at Patuxent from wild eggs taken in 1968 and 1969 were studied in a group enclosure in which they had been held since 1970. The birds showed a strongly developed linear dominance hierarchy that appeared to obstruct reproductive behavior, but no strong pair bonds developed.

Each of three high-ranking birds (presumably males) showed barely recognizable affiliation with three separate low-ranking birds. In the fall these potential pairs, plus another presumed male and female, were placed in separate visually isolated enclosures, 55 by 180 feet in size, to allow pair bonds to develop. Three of these pairs formed solid pair bonds during the spring breeding season, and copulations were attempted by all three males. In every case observed, copulation attempts were disrupted when the females became aggressive. Two of the pairs built nests in 1974, but no eggs were laid before the onset of the summer molt.

Light-footed rail populations surveyed.—The endangered light-footed clapper rail has been found in seven southern California marshes,



Female Puerto Rican parrot at entrance of nest cavity (top). This cavity has been occupied by parrots for at least 6 consecutive years. The pearly-eyed thrasher (bottom), in competition with the parrot, also nests in tree cavities. (Photos by Noel Snyder, top; Helen Snyder, bottom)

but only two areas appear to have more than about 50 rails each. The California population total may be fewer than 500 rails, but others may occur in northern Baja California.

More than 900 Yuma clapper rails counted in 1973.—The Yuma Clapper Rail Recovery Team conducted a thorough census of this rail in its known habitat 14–26 May 1973 to provide base population estimates for future evaluation of the subspecies' endangered status. Survey areas were covered by boat, on foot, and by car. Rail responses were elicited by taped "clatter" calls which were played for 3 to 10 minutes at selected stops or continuously while drifting in a current or using an electric trolling motor.

A total of 910 Yuma clapper rails were located in an area encompassing the lower Colorado River from Davis Dam near Needles, Calif., south into the Colorado Delta of Mexico (300 miles), adjacent lakes and ponds, the lower Gila River, and the Salton Sea. Of these, 415 birds were located on Federal or State wildlife refuges. On the basis of the census, it was judged that the Yuma clapper rail is not now in immediate danger of extinction.

Black rail populations in jeopardy.—Many west coast marsh areas have been altered or eliminated and the California black rail has nearly disappeared as a consequence. In Arizona, two small populations have been discovered in marshes adjacent to the Colorado River near Yuma. Late in 1972, it was learned that two projects immediately threatened these marshes, the only inland habitat known to be inhabited by the subspecies.

In March 1973, efforts were begun to ascertain the distribution and the preferred habitats of the rails in the Colorado River System. A total of 106 black rails were located within the area from Laguna Dam north to Clear Lake, a distance of about 20 miles, most being just above or below Imperial Dam. Only 14 birds were located in a refuge area; the rest were in areas subject to reclamation, recreation, or pest control operations.

These Colorado River populations may be the largest breeding segment now in existence in the entire range of the California black rail. The birds are in continuing danger of loss of habitat through reclamation and loss of their food supply through pesticide application. (Arizona State University, contracted research.)

Status of the Puerto Rican parrot.—Only 16 Puerto Rican parrots are known to exist in the

wild and 12 are paired. Two of the six pairs laid eggs in 1973, and at least two other pairs attempted to reproduce. Trees in the territories of the four pairs not known to have laid eggs had a striking dearth of good nesting cavities—only two cavities large enough and dry enough to serve as parrot nests were located. Since nest boxes placed in parrot territories in the past have not been occupied by parrots, present efforts are directed at the manual improvement of natural cavities.

In addition to the lack of nest sites, the parrots face competition for the sites that do exist, particularly from the abundant pearly-eyed thrasher. The parrots are clearly dominant over thrashers but do not actively defend their nests from this species and the significance of competition with thrashers is unclear.

There are nine parrots in captivity including five taken this year and kept in Puerto Rico, three at Patuxent, and a single bird in private hands in San Juan. The total population of the Puerto Rican parrot now stands at a minimum of 25 birds.

Hispaniolan parrot reared.—Hispaniolan parrots are being studied as prototypes for the closely related, endangered Puerto Rican parrot to develop techniques and procedures that will permit more efficient management of the threatened form. One of the captive pairs laid



Hawaiian crow feeding nestlings. The nestlings are two of eight known to have been produced in 1973. The nest is in an ohia tree on Mt. Hualalai, island of Hawaii, at an elevation of 3,400 feet. (Photo by Paul C. Banko)

a clutch of four eggs during the last week of March 1973, and hatched two young after approximately 25 days of incubation. One chick disappeared during the 2nd week but the other successfully fledged when it was 51 days old.

Hawaiian crow's status reviewed.—Hawaii has had a history of ecological devastation which began immediately after discovery of the Archipelago by Captain Cook in 1778. More species of birds have become extinct in Hawaii—and more kinds remained threatened—than in any other biological province on earth.

The Hawaiian crow, or Alala, is endemic to the island of Hawaii. Enough historical evidence has now been gathered to estimate that this species once existed in the low thousands on the western and southern flanks of Mauna Loa. Today fewer than 50 are known.

In 1973, four distinct breeding subpopulations were located. Seven nests of nine breeding pairs were found, all in the upper zone of historic

range from 3,320 to 5,480 feet elevation. Six fledglings were produced—three of these were judged to be in danger and were captured for research in confinement; the remaining three were individually marked and released. Two other fledglings were produced by a pair from an unlocated nest, making a total of eight Alala known to have been produced in 1973.

The 9 known breeding pairs of Alala, 1 nonbreeding pair, a group of 3, and a nonbreeding flock of 12 make a total of 35 Alala in adult plumage. These 35, plus 5 fledglings known in the wild and 3 in captivity, established the known extant population of Alala at 43.

Dusky seaside sparrows censused.—Three censuses of singing males were conducted (9 and 23 May; and 28 June) in 1973 in two impoundments on the Merritt Island National Wildlife Refuge. Results showed a continuing downward population trend that has been evident since the study began in 1969.

GREAT LAKES FISHERIES

Eastern Fish Disease Laboratory

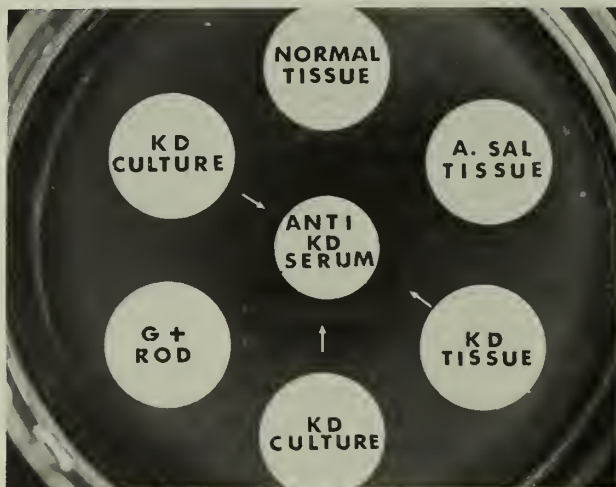
Fish diseases in the Great Lakes.—Definitive and rapid serological diagnosis of salmonid kidney disease (KD) was developed. The test employs rabbit antiserum and diseased fish tissues which are reacted in gel diffusion medium. Formation of a visible precipitate between the antiserum and test tissues and a control of known kidney disease constitutes a positive diagnosis. The test eliminates the need to culture the bacterium, and yields results in less than 24 hours.

Hagerman redmouth disease, caused by an intestinal type bacterium, has been known exclusively from the West. However, we have serologically identified the organism as the cause of serious disease in rainbow trout from Tennessee and the Great Lakes area.

A 2-day workshop on whirling disease, co-sponsored by the Eastern Fish Disease Laboratory and the Division of Federal Aid, attracted 22 participants from Canada, the Northeast, and several States of the Great Lakes basin. Current status of research was reviewed and instruction was provided in methods for spore release and concentration newly developed at the Eastern Fish Disease Laboratory.

Fish Control Laboratory

Selective larvicides for sea lamprey control.—Efforts to reduce the numbers of the parasitic sea lamprey in the Great Lakes depend largely



Diagnosis of salmonid kidney disease. Arrows show precipitin bands formed by reaction between rabbit antiserum (center well) and both the control kidney disease cultures and infected trout kidney extract. The lack of reactions between antiserum and remaining outer wells add diagnostic specificity to the test.



Larval sea lampreys are exposed to lampricides in flow-through tests which simulate natural streams. (Photo by Leif L. Marking)

on the use of a selective larvicide, TFM, which is a halogenated nitrophenol. Personnel at the Fish Control Laboratory continued their studies on the environmental effects of lampricide applications. Research during the year probed into the effects on nontarget organisms, residue levels, and the fate of lampricides and their metabolites in the environment.

In a test of the effects of TFM on other animals, 10 species of invertebrates were exposed to TFM. The 96-hour LC_{50} 's for TFM (39.45%) ranged from 555 to 2.5 ppm in tests involving turbellarians, mollusks, oligochaetes, crustaceans, and insects. Backswimmers were the most resistant species tested. In tests thus far, TFM has shown greater toxicity to fish than to most invertebrates.

Exposures of sea lamprey larvae to TFM under varying water chemistries indicate that pH has a greater effect on toxicity than temperature or water hardness. At pH 6.5, TFM was approximately nine times as effective as at pH 8.5.

Residue levels in fish following exposure to 1.0 ppm TFM for 12 hours indicate that after 24 hours of withdrawal, lake trout and white bass exposed to 1.0 ppm contained no detectable residues. Yellow perch contained only 0.04 ppm.

Applications of TFM are made in tributary streams of the Great Lakes. Thirty-six adult lake trout from Lake Superior and 26 from Lake Michigan, and 25 chinook salmon from Lake Michigan carried no residues, even though TFM had been used in some areas for 15 years.



Sport fishing vessels headed for the open water of the Great Lakes to fish for lake trout and coho salmon. Control of the sea lamprey and the stocking of these species have combined to produce the most successful and popular sport fishery in the history of the Great Lakes. (Photo courtesy of Michigan Department of Natural Resources)

In tests of the metabolism and excretion of TFM, rainbow trout were exposed to a solution of well water containing 5 ppm of the lampicide TFM at 12° C for 0.25, 0.50, 0.75, 1, and 2 hours to study blood levels and to learn how the fish metabolize the larvicide.

Elimination of TFM from rainbow trout plasma after exposure to a 1-ppm solution for 12 hours at 12° C is rapid; no detectable levels were present after 4 hours of withdrawal in fresh water.

The turnover of TFM in bile presents a different picture. Levels of conjugated TFM increased from 510 ppm at 0-hour withdrawal to 1,130 ppm at 12 hours. However, between 12

and 24 hours of withdrawal, concentrations of both free and conjugated TFM declined by factors of seven and three, respectively.

Although the lampricide TFM is persistent in laboratory tests, residues do not occur in the environment. One possible explanation was that TFM undergoes photodecomposition when exposed to ultraviolet light. After 96 hours of exposure to ultraviolet light or sunlight, however, there was no apparent loss in biological activity of TFM.

The effect of sunlight and an ultraviolet light source on TFM was also quantified by using ^{14}C -TFM. After solutions of ^{14}C -TFM were exposed to sunlight for 24 hours (three 8-hour days of sunlight) 90% of the TFM activity remained. Likewise, there was no appreciable loss of TFM activity in samples aged in darkness.

Mixtures of TFM and the molluscicide Bayer 73 (98:2) are more economical than TFM used alone. Temperature, hardness, and pH had little effect on the toxicity of the mixture to larval lampreys. Although increased effectiveness has been observed, this action is the result of additive toxicity rather than synergism.

The toxicity of TFM alone to crayfish was determined to be 12.9 ppm. Crayfish were not affected by 0.15 ppm of Bayer 73, the highest level normally applied in streams.

Chemicals that enter the environment are frequently recycled through the bodies of aquatic organisms due to ingestion with water, ingestion as part of the diet, or absorption through the gills and skin. Test chambers simulating stream conditions were used to expose burrowed sea lamprey larvae, brook trout, steelheads, and crayfish for about 10 hours in flowing water with a gradual diminution of concentration. Bayer 73 was not selective for either burrowed or free-swimming lampreys over trout. The TFM:Bayer 73 mixture was more toxic to free-swimming sea lamprey larvae than to brook trout or steelheads but this selectivity was not evident when the larvae had burrowed in the substrate.

Lamprey embryos (within the egg) were exposed to TFM, Bayer 73, and the TFM:Bayer 73 mixture in waters of varying hardnesses for 24 hours at 18.4° C. All mixtures proved less toxic in hard than in soft water. All chemicals also proved less toxic to embryos than to larvae,

indicating that unhatched embryos could survive larvicidal applications in streams.

Tests to determine the influence of temperature, hardness, and pH on the toxicity of Bayer 73 to sea lampreys indicate that none of these affect its action.

When Bayluscide (a 70% wettable powder formulation of Bayer 73) was tested against larval lampreys, rainbow trout, and mayfly nymphs, selectivity against lampreys was observed. Mayflies were more than 15 times as resistant to Bayluscide than lampreys, and over 10 times more resistant than the trout.

Other research on sea lampreys.—In a test of chemosterilization, adult lampreys injected with P,P-bis(1-aziridinyl)-N-methyl phosphinothioic amide (a chemosterilant) at rates between 10 and 100 ppm were rendered sterile. In matings between injected and normal individuals, less than 0.7% of the fertilized eggs developed to the burrowing stage.

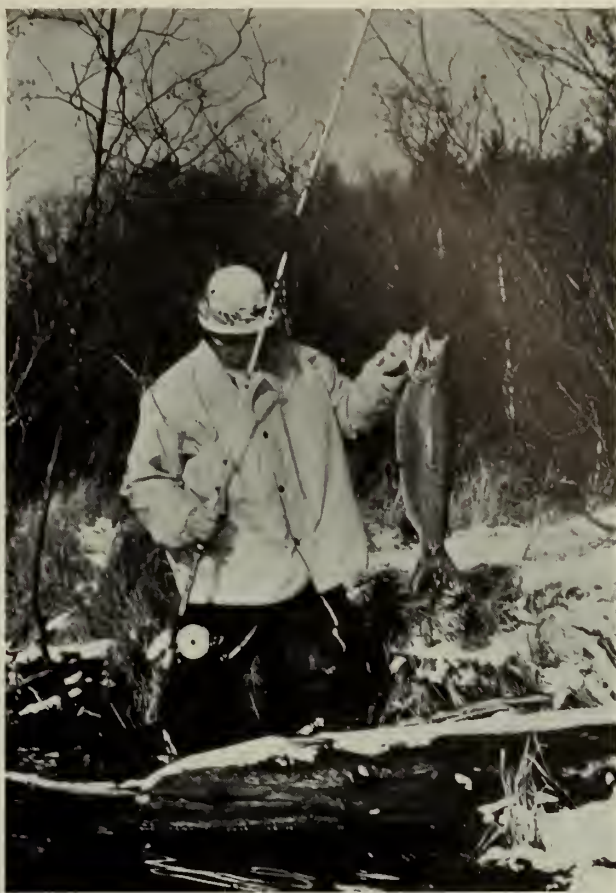
Downstream migrations of transforming sea lampreys have been monitored in the Ocqueoc River, a tributary of Lake Huron, since 1962. The 482 recently metamorphosed lampreys captured in 1973, the lowest number on record, represent only 0.8% of annual pretreatment runs (average 63,502). Adult sea lampreys, which are trapped each year as they make spawning runs up the Ocqueoc River, also decreased markedly. The 673 lampreys captured in 1973 represented the lowest number on record and reflects the success of lampricidal programs conducted in tributaries of Lake Huron and especially in the Ocqueoc River.

All species of lampreys found in the Great Lakes are now under artificial culture. To rear lampreys, it will be necessary to hold many year classes of larvae under culture before the cycle is completed. Before the 1974 spawning season, a total of 17,800 larvae of four species and of various year classes were on hand at the Hammond Bay Biological Station.

Growth and survival of cultured larve increased when the temperature in rearing units was raised above that of ambient lake waters. Temperatures between 16 and 21° C provided excellent results.

Great Lakes Fishery Laboratory

Investigation of the fisheries of the Great Lakes began in 1927 when a permanent pro-



A large steelhead (lake-run rainbow trout) from a tributary stream of the Great Lakes. A popular fish for many years, the species was decimated by the sea lamprey during the 1950's. After control of the sea lamprey in the Upper Great Lakes in the 1960's and early 1970's, steelheads—like lake trout—recovered strongly and are again abundant. (Photo courtesy of Michigan Department of Natural Resources)

gram of Federal fishery and limnological research was first established at Ann Arbor, Mich. The work is now carried out by the Great Lakes Fishery Laboratory, which is located on the North Campus of the University of Michigan at Ann Arbor. Supporting field units are biological stations at Ashland, Wis., and Sandusky, Ohio; vessel bases at Cheboygan and Saugatuck, Mich.; and four 45- to 65-foot research vessels (R/V), the *Cisco*, *Kaho*, *Musky II*, and *Siscowet*.

The mission of the Laboratory is to describe and understand the ecology of the Great Lakes and to develop the knowledge required for the conservation and enhancement of the fishery

resources. Summarized here is recent research on a number of subjects that contribute toward the accomplishment of that mission: the continuing assessment of fish stocks in each of the Great Lakes (particularly lake trout, bloaters, and alewives in the upper Great Lakes and walleyes and yellow perch in Lake Erie); the physiology and behavior of fishes as determined by laboratory studies that have potentially wide application to the natural Great Lakes environment; chemical contaminants (especially DDT, PCB's, and mercury) in fish and the environment, and their uptake by fish as observed in the laboratory; and the physical, chemical, and biological characteristics of the Great Lakes as an environment for fish.

Assessment of Lake Superior fish stocks.—Changes in the lake trout population have been followed in Lake Superior since 1959. Under special permits or contracts, commercial fishermen using 4-1/2-inch-mesh gill nets at several locations in Minnesota, Wisconsin, and Michigan regularly provide materials for determining population size and structure, contribution of fin-clipped hatchery fish, and incidence of sea lamprey wounds and scars.

Following an 85% reduction in sea lamprey abundance in 1961, closure of the commercial fishery in 1962, and intensive stocking in the late 1950's and 1960's, the abundance of lake trout rose to the highest level in 30 to 40 years in 1970–71 in Michigan and Wisconsin, but remained below normal in Minnesota. In 1971–73, declines in abundance in Wisconsin (42%) and Michigan (8%) and a 45% increase in Minnesota mainly reflected changes in stocking rates in the late 1960's. The decline in Wisconsin, however, was also associated with increased sea lamprey wounding and commercial exploitation. In September 1973, after treatment of lamprey producing streams was intensified in 1972–73, sea lamprey wounding rates declined sharply in all areas.

Although some natural reproduction of lake trout has occurred each year since 1955, it is insufficient to support the population in southern Lake Superior, except in the vicinity of Gull Island Shoal of the Apostle Islands region, where most of the spawners are native fish. Experimental trawling indicated that the 1973 year class of native young-of-the-year lake trout in this area was the strongest in 15 years.

Evidence from spawning-run surveys in 1972–73 suggests strongly that most hatchery-reared lake trout do not spawn in spawning areas frequented by native lake trout, but move into shallow, often sandy, areas along the mainland shore (near the planting sites) that may be unsuitable for incubation of eggs. Fish from an experimental planting in 1965 in a traditional lake trout spawning area tended, however, to home back to that reef to spawn in 1971–73. Planting schedules in Wisconsin and Michigan waters are being altered to include plantings by boat on known former spawning reefs whenever possible.

The gill net, long used as the standard sampling gear for assessing lake trout populations, is usually highly selective for a limited size range of fish of most species. Inasmuch as the average size of lake trout in Lake Superior catches has increased greatly over the past 12 years, knowledge of the efficiency of 4-1/2-inch-mesh gill nets in catching various sizes of lake trout is necessary for evaluating the results of assessment fishing. Accordingly, series of 12,000-foot gangs of gill nets with equal amount of 4-, 4-1/2-, 5-, 5-1/2-, and 6-inch-mesh webbing were fished in 1973; they caught a total of 2,408 lake trout 9 to 36 inches long. Almost half the lake trout in the 4-1/2-inch webbing were entangled by their teeth or mouthparts rather than being gilled or girdled. Because of this strong tendency of lake trout to entangle in the nets, size selectivity is greatly reduced. The 4-1/2-inch net appears to be almost equally efficient for all sizes of lake trout in the 20- to 30-inch range. Although further definition of net efficiency is needed for fish longer than 30 inches, the study resolved several questions about the adequacy of our sampling and interpretations of results over the past 15 years. In particular, the crucial year-by-year evaluations of mortality rate during the period of sea lamprey control and lake trout population buildup appear to have been sound.

Until 1972 most experimental trawling and gill netting in southern Lake Superior was specifically pointed toward evaluating various aspects of lake trout stocking and rehabilitation. Sampling was concentrated at locations and depths where lake trout are usually most abundant. As the problems of lake trout rehabilitation became less critical, some effort was shifted



The borrowing amphipod, *Pontoporeia affinis*, is an important fish food organism in the Great Lakes. (The parallel lines of the grid are 5 mm, about 1/5 inch, apart.) (Photo by Joseph Worswick, Jr.)

to assessment of changes in other species, especially those that make up the forage food base of lake trout and other large salmonid predators. In 1973-74, the surveys were expanded to include all depths from 15 to 285 feet, so that delineation of depth distribution could be extended to all available species. However, nearly all species and some size or age groups within a species were found to be distributed over different depth ranges. Adequate sampling at fixed depths would require at least 30 trawl tows at each locality over a short period of time. If enough index stations were fished to yield reasonably representative population samples, the total number of trawl tows required would be prohibitive.

In 1973 a new trawling technique was initiated—trawling across the full depth range, from shallow to deep water, rather than along selected contours. This method requires constant adjustment of the length of the trawl cables, but the results appear encouraging. All species caught in on-contour tows were also taken in down-the-bank tows. It is hoped that the effort needed at each index station can eventually be limited to three tows each season.

The lake whitefish is the most valuable commercial species in Wisconsin waters of Lake Superior. The abundance of young-of-the-year whitefish has been measured by trawling each

fall for nearly 10 years, and substantial numbers of age-II and age-III whitefish have been taken in experimental gill nets set for lake trout. Gill net catches of these young whitefish increased sharply in 1973, suggesting the presence of strong 1970 and 1971 year classes. Trawl catches of young-of-the-year whitefish in the fall of 1973 were the highest in 15 years. Moreover, the commercial catch of whitefish increased from only 46,000 pounds in 1965 to more than 200,000 pounds in 1971 and 1972. Although the catch fell to 182,000 pounds in 1973, the presence of several good year classes and the outstanding strong 1973 year class should sustain the generally upward trend in whitefish production.

The lake herring was once the most abundant commercial species in Lake Superior, producing more than 10 million pounds annually for several decades. During the 1950's and 1960's, however, herring stocks declined drastically and the species may now be threatened with extinction in U.S. waters. The cause of the decline is unknown, but predation by rainbow smelt on herring fry, food competition of smelt with herring fry, and overexploitation have been suggested as probable causative factors. In May 1974 a study of herring fry abundance and food habits in relation to predatory and competitive relationships with smelt was begun in an area of low abundance of adult herring (Wisconsin) and the only remaining area of high abundance (Black Bay, Ontario). Towing for herring fry and plankton, and bottom and midwater trawling for smelt began shortly after the ice cover broke up, while the hatch was in progress, and continued through the end of June. Large samples of herring fry, plankton, and smelt were taken.

Although data analysis is incomplete, one significant fact is already apparent from observations in the field: Abundance of newly hatched herring fry was about 60 times as high in Black Bay as in Wisconsin. Regardless of any possible effects of smelt on fry abundance, the difference in the size of the hatch alone suggests that the spawning stock and egg deposition are now inadequate for production of strong year classes in Wisconsin waters.

In August 1973 a study was begun of a wall-eye population in Chequamegon Bay, southwestern Lake Superior, that has long supported

an important sport fishery and, since 1972, a commercial gill net fishery by Indians of the Bad River Reservation. Intensive trawling over an 8-day period yielded 98 walleyes, 4.5 to 28.8 inches long. Most were tagged and released. A strong year class of age-I fish dominated the catch and only three young-of-the-year were caught. Walleye fry were planted in 1972 and 1974 (100,000 each year) but not in 1973. Additional future sampling may permit evaluation of alternate-year planting of fry, and returns should provide information on the effects of exploitation.

A 3-year study in the Apostle Islands region of Lake Superior is yielding valuable data on the composition and abundance of fish and invertebrate forage stocks, and the use of various invertebrate forage species by fish. The more abundant fishes observed during the study were rainbow smelt, ninespine stickleback, lake whitefish, and slimy, spoonhead, and fourhorn sculpins. Lake trout, bloater, trout-perch, burbot, pygmy whitefish, and round whitefish were also commonly collected. Abundant and heavily utilized invertebrates included the calanoid copepods *Limnocalanus macrurus* and *Senecella calanoides*, burrowing amphipods, opossum shrimp, and several species of midge larvae and fingernail clams. Burrowing amphipods constituted over half of the diet of most of the fishes. Opossum shrimp were heavily utilized by fishes that occupy the deep waters where it is abundant.

Assessment of Lake Michigan fish stocks.—Although stocked lake trout spawned heavily in Lake Michigan each year in 1971–73, no young have been collected. (Restocking of lake trout began in 1965, following the disappearance of native stocks in the mid-1950's as a result of sea lamprey predation.) The reason for this apparent lack of reproduction is not known, but speculation has centered on the possibility that the shallow water where most spawning has occurred is unsuitable for egg or fry survival, due to severe wave and ice conditions. One reason suggested for the movement of most of the stocked fish into very shallow water to spawn is that they are responding to an instinct to home to their planting sites, most of which have been along shore. If this theory is correct, it would be reasonable to assume that fish stocked on traditional deeper

spawning grounds would later return there to spawn, and thereby increase the chances of successful reproduction. A planting made in 1966 on the Milwaukee reef, a midlake spawning ground heavily used by native lake trout before they were decimated by the sea lamprey, provided an opportunity to check this possibility. A gill net fished on the reef from the R/V *Cisco* in early November, at the height of the spawning season, produced several ripe male and female lake trout which had been stocked on the reef. Although a few ripe fish from plantings made elsewhere were collected in the same net, the rather large proportion of those in the catch which had been stocked there suggested that stocking lake trout on known spawning grounds improves the probability of developing spawning runs to them. The lack of young in experimental catches thus far suggests, however, that spawning on the reef has been unsuccessful, although the number of spawners may have been so small that the few surviving progeny they might have produced have escaped detection.

In a 2-year study of the relative survival of two sizes of fall-stocked fingerling lake trout, plantings of 100,000 each of the two groups of fish were made off Grand Haven, Mich., in 1971 and again in 1972. In each year, fish-culturists had accelerated the growth of one group (here termed AG) by feeding a special diet and elevating the rearing temperatures; the fish averaged about 130 mm long when released. Fish of the other group (NG, normally grown) were fed regular food and reared at the usual hatchery temperatures; they averaged about 90 mm long when planted. The immediate objective of the study is to determine whether increasing the size of fall-stocked lake trout improves survival. (Normally grown lake trout stocked in fall as fingerlings generally do not survive as well as those stocked in spring as yearlings.) Sampling was done with gill nets and trawls.

The 1973 sample ratio of AG to NG fish among lake trout stocked the previous fall was not greatly different from that recorded in 1972 (189:83 vs 157:80). Thus in both years, roughly twice as many AG as NG fish were collected during their first year in the lake. Among fish in their second year in the lake, however, the advantage of AG over NG fish (144:116) was much less pronounced. The reason for the



Heavy catch of alewives in a gill net being hauled aboard the R/V *Cisco* during a study of vertical distribution of alewives in southeastern Lake Michigan, July 1973. (Photo by LaRue Wells)

change in ratio of the two groups from the first to the second year in the lake is not known. A higher mortality among AG than NG fish in their second year seems unlikely, but cannot be ruled out. Other possibilities are that AG fish, which have maintained their size advantage, have become less vulnerable to the gear than the others; or that they have dispersed more widely, either to other parts of the lake or into mid-depths out of the effective range of the sampling gears. A clearer picture of the comparative survival of the two groups should emerge after the fish have been sampled for one or more additional years.

Gill net catches showed convincingly that the marked increase of yellow perch that has occurred along the east shore of Lake Michigan

since a precipitous decline in the mid-1960's has failed to materialize along the west shore. Catches of perch at several locations along the east shore from Frankfort, Mich., to Michigan City, Ind., were moderate to large in all areas, whereas those along the west shore were small at Waukegan, Ill., and nearly nil at Milwaukee and Sheboygan, Wis. Other observations indicated that yellow perch appear to favor rocky over sandy bottom for spawning in the southeastern and east-central portions of the lake. In paired gill nets set on the two bottom types in several locations during the spawning season, perch catches on sandy bottom averaged only 19% of those on rocky bottom.

In a study of the vertical distribution of alewives in southern Lake Michigan, gill nets



Alewives being removed from a portion of the gill net which has just been released from the jaws of a hydraulic gill net lifter. The net is pulled from the water through a window in the enclosed foredeck of the vessel, and passes around the head of the lifter in a clockwise direction. (Photo by LaRue Wells)

were set obliquely, surface to bottom, off Saugatuck on five occasions, daytime and nighttime, from mid-April to mid-October. In conjunction with the gill net effort, continuous acoustical surveys and day-night series of trawl tows were also made. Catches in daytime sets were apparently strongly influenced by net avoidance, and were therefore not representative of vertical distribution. Net avoidance in daytime was particularly obvious in summer and fall, when alewives were absent in the catches at all levels including the lowermost, although they were caught in large numbers during the day with bottom trawls. In spring the alewives did not avoid the daytime oblique nets altogether. In late May, for example, they were taken in rather large numbers in the lower 8 fathoms of the nets where total depth was 26 fathoms. Catches in nighttime sets appeared to represent accurately the distribution in hours of darkness. During periods when water

in the upper levels was relatively cool, alewives at night were distributed surface to bottom, although numbers were small near the bottom. In early September, alewives at night were common near the surface in upwelled water of 14°C , where bottom depth was 13 fathoms, but were apparently lacking in warmer upper waters (21°C) where bottom depth was 26 fathoms. (Young-of-the-year alewives, which were not vulnerable to our gill nets, commonly occur at the surface at temperatures above 21°C .) Much larger day than night bottom trawl catches, and changes in acoustical tracings from day to night, indicate that alewives often migrate upward at night.

To delineate nursery areas of important fishes that might be affected by the water intakes or thermal effluents of existing or proposed power-generating plants along the shores of Lake Michigan, biologists gathered data on abundance and vertical distribution of fish fry

inside the 5-fathom contour during several periods between early May and mid-August. Series of samples were collected with plankton townets at six localities along the east shore from Frankfort to Benton Harbor, Mich., and at five localities along the west shore from Kewaunee, Wis., to Waukegan, Ill.; limited sampling was done at six other localities. Most collection sites are near powerplants. During May, rainbow smelt fry were common to abundant from Saugatuck, Mich., to Benton Harbor, but scarce elsewhere. No fry of other species were taken in May, except for several yellow perch at Saugatuck (probably hatched in tributary waters, since perch had not yet begun to spawn in Lake Michigan). In late June, alewife fry were common throughout the near-shore zone of the eastern shore and along the western shore from Waukegan to Milwaukee, but scarce north of Milwaukee. Except for a few yellow perch in most collections made along the east shore, no other fry were observed in the summer samples.

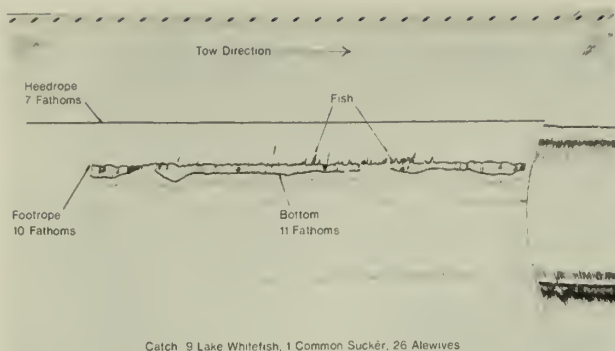
Dynamics of Lake Michigan bloater and alewife populations.—A continuing synthesis of biological data on Lake Michigan bloaters (one of several species of deepwater ciscoes widely known as chubs) provides a basis for the development of uniform lakewide management of the fishery by State conservation agencies. Significant in this study are changes in the age structure of bloaters available to standard trawls in southern and northeastern Lake Michigan during the period 1963–73. Yearly abundance indices derived from sample catches of age-V and older fish off Saugatuck indicated that five comparatively strong year classes produced in 1960–64 contributed collectively to the high commercial production of bloaters in Lake Michigan in 1967–70, which ranged from 9.1 to 10.9 million pounds per year. Thereafter, year-class strength decreased sharply: in 1973 the 1968 year class contributed only 13% as many fish to the index catch at age-V as did the average year class produced in 1960–64.

A long-term decline (20% per year, 1960–73) in the availability of bloaters to trawls in southern Lake Michigan, attributable to diminishing recruitment, suggests that scarcity of spawners is now seriously limiting the innate productivity of the species. Continued

heavy exploitation of bloaters while they are exposed to sustained competition from alewives and smelt could negate chances for recovery. Recognizing the gravity of this matter, the Lake Michigan Committee of the Great Lakes Fishery Commission named a technical working group to develop interim allowable harvest quotas for bloaters in 1975, as well as means for facilitating the computation of quotas in the future. During the first meeting of the technical committee in late May 1974, data pooled from State and Federal files were reviewed and interim quotas were considered.

An extension of an annual survey of fish stocks into areas of central and northern Lake Michigan in fall 1973 provided a basis for estimating the total weight of bloaters, alewives, and associated species currently available to fishing gear. The stratified geographical frame used in the estimation procedure included eight regional sectors, each divided into strata representing depth zones of 0–20, 21–40, 41–60, and 61–80 fathoms. The lakewide estimates for each species consisted of a summation over all strata of the catch per acre trawled, multiplied by total acreage. These calculations produced estimates of 15 million pounds of bloaters and 220 million pounds of alewives age I and older available in the bottom waters of the lake proper during October–November 1973. Comparison of these estimates with those computed previously for all seasons in 1963–65 combined (bloaters 139 million pounds and alewives 237 million pounds) reflects the serious drop in abundance of bloaters and the continued high abundance of alewives over the past decade. Although these computations provide management agencies with a good indication of the large quantities of fish in Lake Michigan, they underestimate the total biomass for at least three reasons: fish at mid-depths are unavailable to the bottom trawl; the trawl is not 100% efficient in capturing fish ahead of it; and trawling has generally been limited to bottom depths of 70 fathoms and less.

Development of midwater fishing gear for Lake Huron studies.—Several midwater trawls fished with hydrofoil doors and an acoustical hookup between net and vessel were tested during operations of the R/V *Kaho* in Lake Huron. The tests led to the development of an effective midwater trawling system that will greatly



Echotrace showing midwater trawl fishing near the bottom (depth, 11 fathoms) in northern Lake Huron. Continuous recording indicates the net's position in relation to the bottom, the presence of fish schools, and the height of net opening (about 18 feet between headrope and footrope). A 20-minute tow produced 9 lake whitefish, 1 white sucker, and 26 alewives. Minutes earlier, a 20-minute tow at the same depth caught 82 whitefish weighing 185 pounds. (Disregard extensive "noise" attributable to high-gain setting of the echosounder.)

facilitate the assessment of Great Lakes fish stocks, particularly those of alewives and rainbow smelt. The heart of the system is a transducer attached to the headrope of the trawl and connected through a two-wire electrical conductor to the ship's echosounder, which produces continuous recordings of the net's vertical opening and fishing depth and of fish entering or below the net. A second echosounder, operating through a transducer in the ship's hull, displays simultaneous information on depth and bottom topography and on the distribution of fish in the water column. Depth of the net's footrope can be closely controlled (to within less than 1 fathom of the bottom) by slight changes in vessel speed.

Routine sampling with the midwater gear, as an integral part of systematic acoustical surveys, is providing researchers with baseline data on the pelagic distribution and abundance of alewives and smelt that heretofore could not be obtained with conventional sampling gear and methods. During trial runs in western Lake Huron, fish detected by the echosounder at mid-depths and near the surface were nearly always alewives and those closer to bottom were nearly always smelt. Off-bottom fish detected far offshore were always alewives.

To gather information on the configuration, dimensions, and performance of trawls while in operation, professional scuba divers observed the mid-water trawls being tested, as well as two standard bottom trawls that have been used in assessment of Great Lakes fish stocks for several years. The resulting measurements will facilitate the estimation of fish density and the projection of standing stocks (biomass) of species vulnerable to each type of trawl.

Assessment of Lake Erie fish stocks.—Walleye stocks of western Lake Erie, consisting mainly of the relatively strong 1970 and 1972 year classes, changed little in 1973. It appears that 80 to 90% of the females of the 1970 year class spawned in 1973, but failed to produce a year class of any significance. Index trawling yielded an average of less than seven young-of-the-year walleyes per hour (15-year average, about nine per hour). The commercial fishery for walleyes remained closed in U.S. and Canadian waters of western Lake Erie during 1973, thereby extending protection of the strong 1970 and 1972 year classes. As a result, spawning adults were undoubtedly more numerous and larger (and therefore produced more eggs per female) in the spring of 1974 than in any spawning season since the late 1950's.

The growth rate of walleyes in western Lake Erie has changed markedly over the years since 1943, when annual sampling was initiated. At that time, walleyes were about 13-1/2 inches long at age II and 15 inches at age III. Growth early in this period, until about 1954, fluctuated only slightly, with no apparent trends. From 1954 to 1966, however, walleye growth increased steadily and significantly. Average lengths increased to about 19 inches at age II and 21 inches at age III. These increases were accompanied by marked decreases in competition for food and space, as suggested by the drop in commercial production of walleyes in Ohio waters from almost 6 million pounds in 1956 to less than 1/2 million pounds in 1962. At about the same time, the Ohio commercial production of blue pike—for many years the other major predator in Lake Erie—dropped from almost 7 million pounds in 1953 to less than 1/2 million pounds in 1958. Although the growth rate of walleyes of western Lake Erie peaked in 1966 and has not increased since

then, it remains one of the fastest known for the species.

Observations over a 12-year period ending in 1973 showed that the rate and regularity of water warming during the spring spawning and incubation periods of walleyes had a direct effect on the density of egg deposits and the resulting year-class strength in western Lake Erie. Slow or irregular warming was not itself detrimental, but the resultant lengthening of the incubation period increased exposure of the eggs to such negative influences as dislodgment from the spawning reefs during spring storms, or siltation and low oxygen tension. It was also determined that walleye year-class strength is governed to a much greater extent by water temperature during early development than by the size of the parent spawning population. No relation was found between reproductive success and fluctuations in size of suitable reef spawning area caused by changes in water level. Apparently the usable spawning area at any water level observed is adequate to serve the limited walleye brood stock.

In eastern Lake Erie, an analysis of fall landings of walleyes from large-mesh commercial gill nets indicated that the 1970 year class was comparatively weak. It contributed only 7% to the total catch, as compared with 38% for the 1971 year class and 37% for the 1969 year class. The relative failure of the 1970 year class may be the first suggestion of instability that has been seen in the eastern basin walleye population; which has usually sustained commercial harvests year after year, with good representation of a number of year classes.

Walleyes tagged in eastern Lake Erie during a study completed in 1973 showed a consistent and restricted pattern of seasonal movement. Fish marked on major spawning reefs during the spring near Barcelona, N.Y., moved eastward along the shoreline during June and July to waters near Buffalo, and by late fall had returned along the south shore to waters near the spawning areas. Most tagged fish were recaptured within 1 mile of the U.S. shoreline. Of the 275 recaptures, only 4 were reported from the central basin of the lake and none from Canadian waters. The discreteness of the walleye populations in the eastern and western basins, indicated by this and an earlier tagging



Determining the age of a fish by projecting the magnified image of its scale. Because annual growth of the scale is proportional to the growth of the fish, the length of the fish at the end of each year of life can be calculated and its growth history reconstructed. (Photo by Robert Reinert)

study in the western basin, is supported by significant differences in growth rate, fecundity, and year-class stability of the stocks in the two basins.

Yellow perch of western Lake Erie continue to show signs of stress and instability. In contrast to earlier years, when older year classes contributed significantly to the fishery, the 1971-73 commercial catch was dominated by 2-year-old fish. More fishing effort is apparently being expended on smaller and younger perch, especially in Canadian waters, resulting in increased landings during 1972-73. How long the perch stocks can withstand this heavier exploitation of younger fish is a vital management concern now being examined by a special committee of the Great Lakes Fishery Commission. The other side of the problem is the relatively poor recruitment of year classes since 1965 in western Lake Erie. Excellent year

classes in 1959, 1962, and 1965 were largely responsible for the record commercial harvests of the past decade. In particular, the 1962 and 1965 year classes contributed strongly to the fishery over several years. Year classes after that of 1965 have been much weaker, and the 1973 year class is also very poor. It is now expected that commercial perch landings will decline from the current 17 million pounds to about 11 million pounds and remain near this reduced level until another series of strong year classes again appears.

The yellow perch stock in eastern Lake Erie appears to be more stable than that in the western part. Data on catch records and biological samples from the fishery indicate that annual production remains steady, growth remains good, and several year classes contribute significantly to the fishery each year.

In an annual evaluation of hatching success of western Lake Erie fishes begun in 1959, relative distribution and abundance of young-of-the-year is determined from systematic sampling with bottom trawls from about mid-June through October. In 1973 the white bass, a valuable sport and food fish of western Lake Erie, produced the strongest year class on record; more than 834 young were taken per hour of trawling, compared with the 1959-73 average of 363. Rainbow smelt, alewife, and gizzard shad produced exceptionally good hatches. On the other hand, poor hatches of walleyes and yellow perch were matched by those of certain forage fishes—trout-perch, emerald shiners, and spottail shiners—which had hatches below the 1959-73 means for these species.

Management of the fishery resources of Lake Erie is being increasingly complicated by declining populations of valuable species such as walleye and yellow perch, by rapidly growing demands of sport and commercial fishermen, and by decades of progressive deterioration of the environment caused by siltation, pollution, and cultural eutrophication. Superimposed on all these complications are conflicting political, economic, social, and philosophical differences between the various jurisdictions as to how each resource should be managed and allocated among the various user types.

Three positive steps in developing better management strategies for important Lake

Erie fish stocks took place during 1973: (1) A Scientific Protocol Committee for the management of Lake Erie walleyes was formed under the auspices of the Great Lakes Fishery Commission, at the request of fishery managers from the United States and Canada. This committee is composed of representatives from the four States bordering the lake, the Province of Ontario, and the Fish and Wildlife Service. The committee's responsibility is to develop a scientific basis for a lakewide walleye quota system, while at the same time fostering recovery of this stressed resource. Data have been inventoried and pooled by all agencies, and computation of mortality rates, sustainable yields, and harvestable surpluses is underway. (2) The Yellow Perch Subcommittee, appointed in 1972 under the auspices of the Lake Erie Committee and Great Lakes Fishery Commission, continued its deliberations. A special report defining the yellow perch problem and presenting appropriate statistical documentation was presented at the 1974 Lake Erie Committee meeting. (3) In November 1973, the Governor of Ohio established a Taskforce on Lake Erie Fisheries composed of five representatives each of sport and commercial fishing interests; four representatives of the Ohio Department of Natural Resources; and three scientific advisors, two from the Fish and Wildlife Service and one from the National Marine Fisheries Service. The task force dealt with such knotty problems as limited entry in commercial fisheries, quota management of resources, commercial fishing fees and regulations, catch and effort reporting systems, and penalties for violations of regulations. Recommendations and revised legislation were submitted to the Governor in February 1974, when the task force completed its work. The legislation was subsequently passed, and signed by the Governor in June 1974.

Assessment of Lake Ontario fish stocks.—The 1972 cooperative survey of inshore fish stocks of Lake Ontario, which was part of the International Field Year for the Great Lakes (IFYGL), produced a large quantity of valuable data, as yet only partly analyzed. They reveal, however, that the lake's inshore fish population consists of at least 56 species, many of which are abundant and widely distributed. The distribution of important predator and



Measuring the oxygen consumption of a lake whitefish during forced swimming in a tunnel respirometer. (Photo by Thomas Ramsey)

forage species varied greatly between locations. Yellow perch were abundant in the lake's eastern outlet basin but were rarely taken in the western and central sectors. White perch were much more widely distributed, although their center of abundance was also in the eastern area. Smallmouth bass, pumpkinseeds, and rock bass were fairly common in the eastern outlet basin but were rarely taken elsewhere. Threespine sticklebacks were taken only along the shore of the open lake and only in small numbers. Spottail shiners were common and widely distributed, whereas emerald shiners were spotty in abundance and distribution. Alewives were abundant in the outlet basin as well as in the open lake. Rainbow smelt were abundant throughout the open lake, but less common in the outlet basin than elsewhere.

Physiology and behavior of Great Lakes fishes.—The introduction of Pacific salmon and the reestablishment of lake trout in Lake Michigan in recent years have been successful pri-

marily because the lake has an abundant supply of suitable forage. As the numbers of these salmonids increase, however, the abundance of alewives, smelt, and native forage fish can be expected to decrease. Knowledge of the forage requirements of salmonid stocks in relation to the abundance of these prey species is necessary to prevent overutilization of the forage base and possibly a long-term reduction in the productivity of the lake for salmonids. To help establish this forage requirement and increase knowledge of the energy flow through Great Lakes food chains, scientists are collecting information on the food-conversion efficiency of coho salmon and lake trout.

Laboratory studies were conducted in which coho salmon held at various temperatures were fed restricted or unrestricted amounts of whole, young-of-the-year alewives from Lake Michigan. Information from this study and from studies of survival, growth, and food of coho salmon in Lake Michigan permitted calculation



Determining the stage of development of eggs and fry of Atlantic salmon (top). Bottom photograph shows eyed eggs and newly hatched fry. (Photos by Robert Reinert)

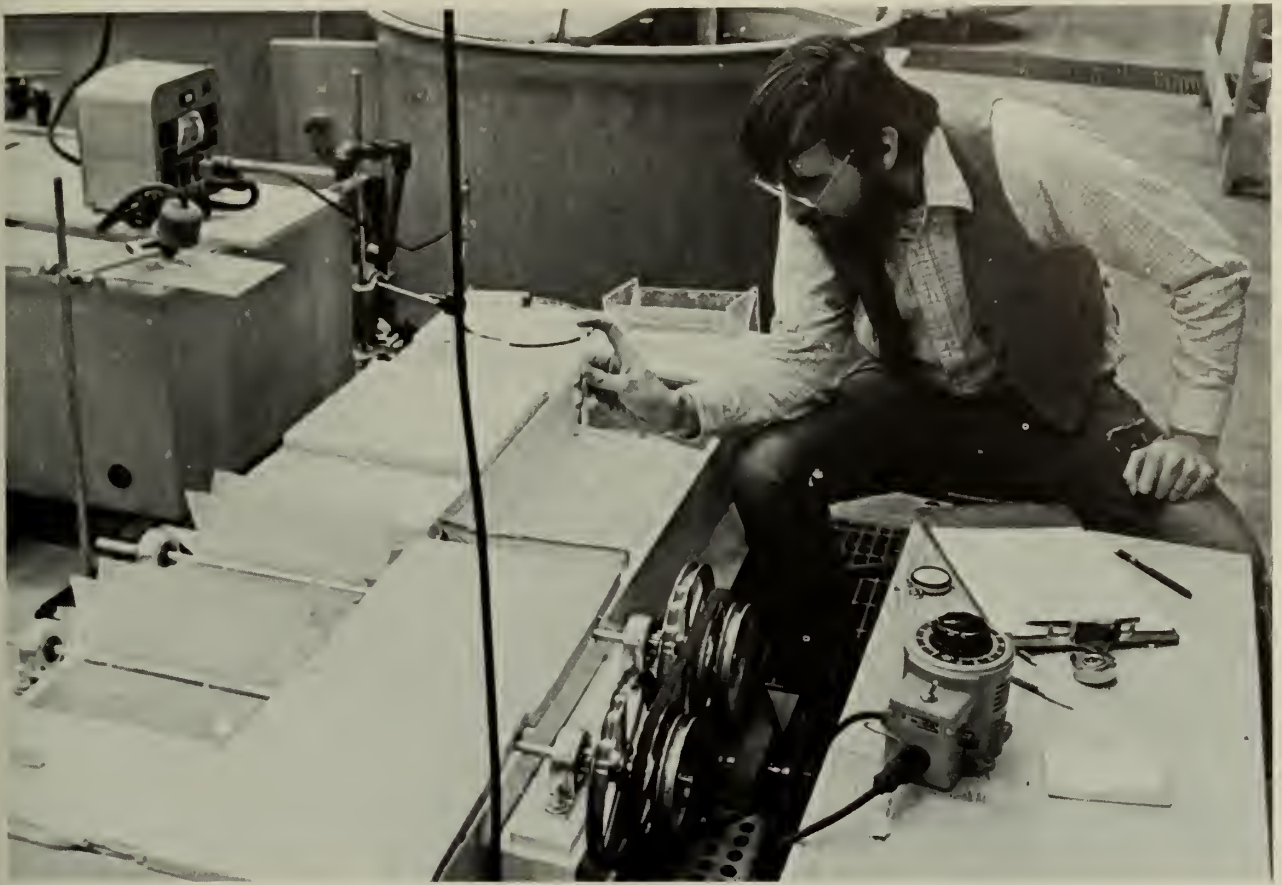
of the forage requirements of coho salmon stocks in the lake. These calculations indicate that between 50 and 125 pounds of alewives are consumed for each mature 8-pound fish produced in Lake Michigan.

Other studies underway to obtain independent estimates of the forage requirements of Great Lakes salmonids include studies of lake trout food requirements; oxygen consumption by salmonids at various swimming speeds (a measure of the food energy burned and hence required at various levels of activity); and the rate and efficiency of digestion of meals of different sizes at various temperatures.

Data on the rate of development of the eggs of lake whitefish, lake trout, and Atlantic salmon incubated at various constant temperatures are being used to develop mathematical models that will permit prediction of the rate of development and time to hatching of these eggs when they are exposed to seasonal temperature changes in the undisturbed natural environment or to temperature changes caused by heated effluents from power-generating plants. The accuracy of these models is to be tested on the basis of data obtained from eggs incubated in the laboratory at simulated natural temperatures. The model for whitefish eggs, which has been completed and tested, yielded a predicted hatching time of 140 days on the basis of the temperatures to which the eggs were exposed—only 3.7% higher than 135 days observed in the laboratory. Preliminary examination of incubation data for lake trout and Atlantic salmon eggs indicates that models developed for these species will probably also have an acceptable degree of predictive reliability.

Egg survival and the percentage hatch of normal, viable fry produced from eggs at constant and fluctuating temperatures were also observed for each of the three species. Eggs exposed to a simulated natural temperature cycle tended to have a slightly lower rate of survival than the best survival obtained among the groups of eggs reared at the various constant temperatures; however, the production of viable, normal fry was highest among groups of eggs incubated at simulated natural temperatures.

The destruction of fish at power-generating plants on the Great Lakes is currently an issue of major concern. Among fish drawn into plant cooling systems, the most commonly observed mortality occurs either when fish are trapped on screens and killed, or when they are subjected to thermal, chemical, and mechanical shocks during passage through the rest of the



Measuring the swimming speed of fish larvae in a flume where a current is produced by a paddle wheel. (Photo by Robert Reinert)

system. Presumably the ability of fish to avoid being drawn into cooling-water intakes is directly related to their swimming ability. To test this ability, biologists tested sac fry of three Great Lakes species—lake herring, rainbow trout, and alewives—in a flumelike apparatus in which a current was generated by a paddle wheel. Preliminary comparisons of sustainable swimming speeds with the velocities of currents at typical cooling-system intakes in the Great Lakes strongly suggest that the fry could not avoid being drawn into the intakes.

The effects on aquatic ecosystems of using natural surface waters for the dissipation of waste heat produced during the generation of electric power have been studied by a number of researchers. Although some of these studies concerned the effects of increased water temperature on fish, apparently none examined the long-term effects of increased water tempera-

ture on the accumulation of contaminants by fish from low concentrations in water. In a study designed to examine the effects of different water temperatures on the amounts of methylmercury or *p,p'*DDT accumulated by fish from water, yearling rainbow trout (initial average weight, 30.6 grams) acclimated to 5, 10, or 15° C were exposed to 234–263 parts per trillion (pptr) methylmercuric chloride or 133–176 pptr *p,p'*DDT for 12 weeks.

Concentrations of mercury and *p,p'*DDT in fish increased with temperature. After 12 weeks of exposure, concentrations of mercury in fish at 5, 10, and 15° C were 1.19, 1.71, and 1.96 ppm; fish held under the same temperature conditions and exposed to *p,p'*DDT contained an average of 3.76, 5.93, and 6.82 ppm. Concentration factors (concentration in fish divided by concentration in water) after 12 weeks' exposure were as follows:

Temperature (° C)	Concentration factor	
	Mercury	p,p'DDT
5	4,352	21,363
10	6,622	43,158
15	8,049	51,355

Prediction of the rate of accumulation and the exact concentration attained by fish in nature on the basis of water temperature alone would be difficult, because accumulation and concentration also depend on a number of other factors, including (1) the amount of time fish are in the warmer water, (2) the initial concentration of contaminants in the fish, (3) the effects of water temperature on the rate of feeding, (4) the amount of contaminants accumulated from food, and (5) the rate of contaminant excretion. Nevertheless, the study clearly shows that an increase in temperature can increase the rate of accumulation of mercury and DDT from water by fish, and suggests that fish living in the heated effluent from electric-power generating stations would tend to accumulate these contaminants more rapidly than fish living in unheated lake water.

Chemical contaminants in Great Lakes fishes.—Contamination of fish from several areas of the Great Lakes continued as a major problem in the management and utilization of sport and commercial fishery resources of the Great Lakes. The presence of DDT, PCB's, or mercury has required the imposition of restrictions on the use of one or more species in each of the lakes by State and Canadian officials. Continuing evaluation of changing trends of these contaminants in fish has revealed, however, an encouraging decline in some contaminants following the control of their use and loss in the watershed. The rapidity of the onset and rate of these declines is impressive evidence of the value and effectiveness of regulatory controls in reducing contamination in large aquatic ecosystems and emphasizes the need for additional controls on remaining problem contaminants.

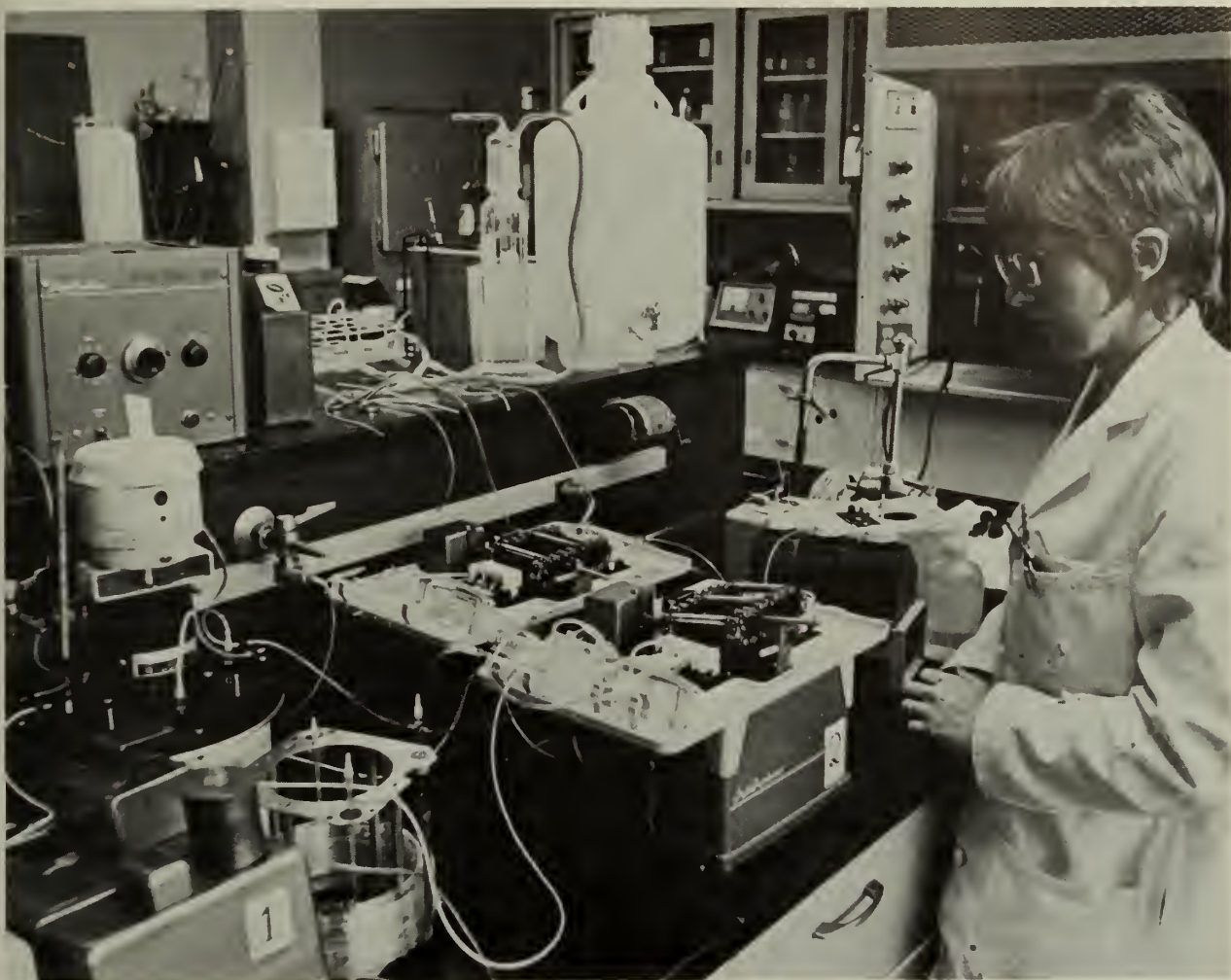
To better understand and predict the behavior of contaminants affecting Great Lakes fisheries, scientists have carried out laboratory studies on (1) the uptake, storage, and excretion of dieldrin and DDT by lake trout; (2) the chemical basis for preferential uptake of various mercurial compounds and the predominance of methylmercury in mercury-contaminated

fish; (3) the distribution of mercury in various tissues of fish; and (4) a potential technique for rapidly determining whether mercury residues in particular fish are the result of past exposure or continuing exposure to methylmercury. A survey of trace metals (arsenic, cadmium, chromium, copper, mercury, selenium, and zinc) in selected species from each of the Great Lakes has also been completed.

Work during the mid- to late 1960's showed that certain sport and commercial fishes of Lake Michigan were severely contaminated by DDT and its metabolites. These data were instrumental in bringing about a ban on the use of DDT by officials of the States bordering the lake in 1969–70. Continued monitoring of DDT concentrations in selected Lake Michigan species has shown a significant decline in average residues since the imposition of the ban. Residues of total DDT in fall collections of bloaters off Saugatuck, Mich., have declined 56%, from the high of 9.9 ppm in 1969–70 to 4.3 in 1972. Average residues in Lake Michigan bloaters are now below the 5-ppm guideline of the Food and Drug Administration (FDA) for the first time since pesticide monitoring was initiated in the lake in 1965. Total DDT residues have similarly declined during the 2-year period in lake trout off Saugatuck (from 19.0 to 11.3 ppm) and coho salmon off Ludington (from 14.0 to 7.3 ppm).

Residues of mercury in channel catfish, rock bass, yellow perch, and walleye from Lake St. Clair have also declined significantly since industrial losses of mercury to the area were greatly reduced in 1970. Samples collected in August 1973 revealed reductions in mercury residues ranging from 58 to 78% in the monitored species since 1970. Although residues in the muscle of channel catfish, rock bass, and yellow perch were below the 0.5-ppm FDA guideline for mercury, those in walleyes (1.2 ppm) continued to exceed the guideline. (Residues of mercury in walleyes continue to be near, or exceed, the FDA guideline in each of the Great Lakes.)

Although encouraging reductions in the levels of DDT and mercury have occurred in some areas of the Great Lakes, contamination of fishes by these and other compounds continued as a major problem in the lakes as a whole. In particular, PCB's were found to be



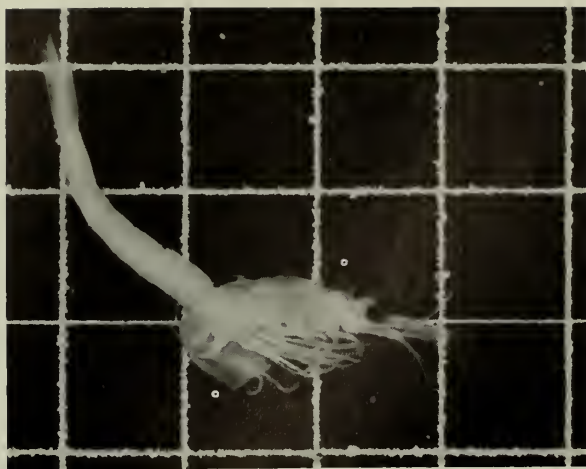
Analyzing water samples on an autoanalyzer for phosphorus concentrations. (Photo by Robert Reinert)

present in amounts near or over the FDA guideline of 5 ppm in several species of fish from various areas of the Great Lakes. Lake Michigan fish were found to be the most severely contaminated; average total PCB residues in fish collected from pesticide monitoring stations were 5.7 ppm for bloaters, 12.9 for lake trout, and 10.9 for coho salmon. These data will serve as a baseline from which future changes in PCB contamination of Lake Michigan fishes will be measured.

A survey of arsenic, cadmium, chromium, copper, mercury, selenium, and zinc in slimy sculpin, smelt, and walleye collected (where possible) from each of the Great Lakes and Lake St. Clair revealed the existence of several species differences within and between lakes

for all of the metals tested. The ranges of average whole-body residues (ppm) in all fish and all lakes for each of the metals were: arsenic, 0.20 to 0.86; cadmium, 0.03 to 0.45; chromium, 0.09 to 0.48; copper, 0.42 to 3.71; mercury, 0.08 to 0.91; selenium, 0.40 to 0.96; and zinc, 12.3 to 28.0. Residues of arsenic were highest in rainbow smelt and walleyes from Lake Michigan and residues of cadmium, chromium, and copper in slimy sculpins from Lake Superior.

Chemical and biological characteristics of the Great Lakes.—Investigation of chemistry and plankton productivity of nearshore waters included characterization of Hammond Bay in northern Lake Huron as a natural, undisturbed, coastal ecosystem representative of the upper Great Lakes. Since March 1973 daily water



The opossum shrimp, *Mysis relicta*, is an important fish food organism in the Great Lakes. (The parallel lines of the grid are 5 mm, about 1/5 inch, apart.) (Photo by Joseph Worswick, Jr.)

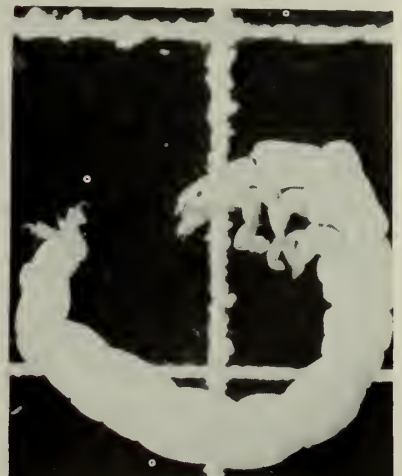
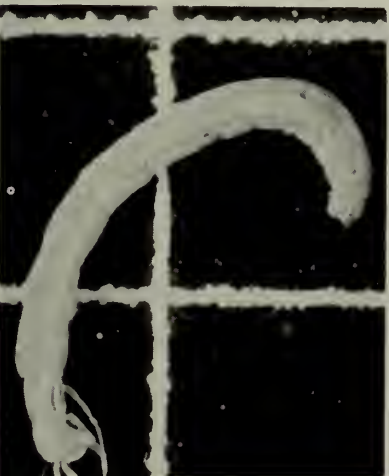
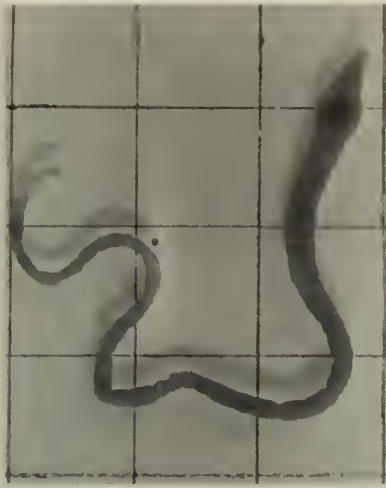
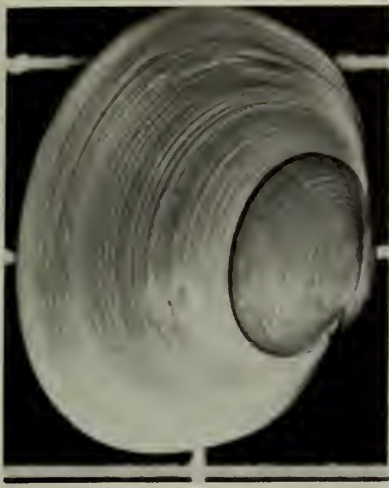
samples for analysis of chemical and plankton composition have been collected from Lake Huron through the Hammond Bay Biological Station's 12-inch water intake. In addition, water samples are collected each month along two transects extending 10 miles into Lake Huron off Hammond Bay, for comparison of chemistry and plankton in inshore and offshore waters. Preliminary results indicate that algae collected through the water intake at the Hammond Bay Station are representative of algae in inshore waters of the bay. Biological productivity in the vicinity of Hammond Bay will be compared with that in other nearshore Great Lakes waters. Differences in rates of productivity will permit identification of nearshore regions where deteriorating water quality threatens the survival of populations of desirable fish species that depend on these regions for reproductive success. Once these regions are identified, they can be managed to preserve spawning and nursery grounds.

Analysis of nutrients and phytoplankton in the lower Great Lakes included a comparison of nutrient levels and phytoplankton composition in the central basin of Lake Erie. Water samples were collected at an inshore and an offshore station at 1- to 2-week intervals from May through November 1967 for analysis of phytoplankton, nitrate, phosphorus, and ammonia (now being completed). The inshore

station was 4.5 miles offshore, at a water depth of 48 feet; the offshore station was 17.9 miles offshore at a water depth of 60 feet. Plankton productivity and nitrate and phosphate levels were higher and algal pulses were more pronounced at the inshore than at the offshore station. Although total numbers of phytoplankton were always higher at the inshore station, patterns of dominance and seasonal succession at the surface (diatom-green-blue green) were similar at the two stations. Numerically, diatoms accounted for less than 25% of the algae in surface waters throughout the summer at the inshore station, but were a more important constituent of the flora in the deeper waters and at the offshore station. Each major algal species exhibited a definite pulse, then became insignificant.

Analysis is continuing of samples of rainbow smelt, alewives, and invertebrate forage organisms collected in Lake Ontario during the International Field Year for the Great Lakes from May through October 1972. The purpose of the study is to determine the food and feeding habits of smelt and alewives, captured in bottom trawls, in relation to the available invertebrate forage base. The diet of smelt was more varied than that of alewives. Although smelt usually contained small amounts of zooplankton, they fed mostly on fish and larger crustaceans such as opossum shrimp and burrowing amphipods. Midges, isopods, mollusks, and ostracods also contributed to the diet. The food of alewives was almost entirely zooplankton, but occasionally included insects and mollusks. Although the alewives were captured by bottom trawl, the few opossum shrimp and amphipods in their diet suggests that the fish either rose from the bottom to feed in midwater, or that small zooplankters were selectively preyed upon. If feeding was off the bottom, the excellent condition of the food in the stomachs suggests that it was freshly ingested and that rather extensive vertical movements of alewives took place frequently—perhaps almost hourly.

The opossum shrimp, because of its widespread distribution in the Great Lakes, is an important food for a variety of fishes, including lake trout and rainbow smelt. Although its life history is fairly well known, relatively little attention has been directed toward measuring its abundance and potential contribution as fish



Representative bottom fauna from the St. Marys River. (Parallel lines in the background grid are about 5 mm or 1/5 inch apart.) The organisms are from left to right: top row, fingernail clam (*Sphaerium striatinum*), segmented worm (*Peloscolex ferox*), snail (*Valvata tricarinata*); middle row, nymph of the burrowing mayfly (*Hexagenia* sp.), leech (*Glossiphonia complinata*), aquatic sow bug (*Lirceus* sp.); bottom row, larval midge (*Chironomus* sp.), feather duster worm having a total length about 1/10 inch (*Manayunkia speciosa*), larval caddisfly (*Phylocentropus* sp.). (Photos by Joseph Worswick, Jr., Robert Nester, and Joseph Moniot).

food. Because most estimates of abundance are based on samples collected during daylight, and because the organism is strongly sensitive to light, the validity of estimates of abundance was suspect.

Statistical analysis of zooplankton data from 88 tows of an epibenthic sled at a single location in southeastern Lake Ontario clearly indicated that time of day and weather conditions must be considered when abundance of opossum shrimp is estimated with this gear. The size of the standard samples reflected the density of opossum shrimp in the path of the sled during tows of identical duration. On heavily overcast days, opossum shrimp densities near the bottom were relatively large during the morning, largest during the early afternoon, and greatly diminished by midafternoon. On clear days, in contrast, densities were small during the morning, increased only slightly by early afternoon, were largest in midafternoon, and decreased sharply during late afternoon. Generally, numbers of shrimp per sample collected on overcast days were larger than the numbers collected during clear weather. The relation between numbers of shrimp per sample and concurrent light intensity indicated that on clear days opossum shrimp migrate downward in the water column near sunrise. (Light intensity determines how close to the bottom they remain.) As the organisms become accustomed to the light they disperse farther from the bottom; however, the increasing light intensity as the sun approaches its zenith prevents them from moving far upward in the water column. As the day progresses and light intensity diminishes, the organisms move farther off bottom; this movement accounts for the afternoon increase in numbers of shrimp per sample, as more animals rise into the path of the sled. The sharp late afternoon decline in catches indicates that the organisms have moved higher into the water column, above the path of the sled.

Investigations of benthic invertebrates of the upper Great Lakes included collections from previously unsampled areas in Lake Superior. Bottom organisms around Isle Royale and along Lake Superior's south shore are sharply limited in diversity and abundance. A burrowing amphipod, the most abundant invertebrate, was only about half as abundant as it is in com-



Verifying catch data from the Great Lakes commercial fishery with modern data-processing equipment. Fishermen from each of eight States bordering the Great Lakes submit records of their catches to their State fishery agency for immediate processing. The forms are then sent to the Great Lakes Fishery Laboratory for editing and final computer processing. The resulting summaries of production and value are useful to various Federal, State, and private agencies in assessing the condition of the fisheries. (Photo by Robert Reinert)

parable areas of Lake Michigan. Aquatic segmented worms (oligochaetes), which ranked second in abundance, were concentrated in the shallower waters. A nearly ubiquitous finger-nail clam was present at all stations except two where the water depth exceeded 300 meters. The remaining conspicuous forms were midge larvae of several species.

A study of the effects on benthic invertebrates of a major channel modification by the U.S. Corps of Engineers on the lower St. Marys River was completed. The 1971-73 study revealed considerable fluctuations in the yearly abundance of benthic forms, but none of the variations could be attributed to any one factor, man-made or natural, except that recent high water levels may have contributed to enrichment of the bottom fauna. Oligochaetes and midge larvae were the dominant forms. Certain crustaceans such as scuds and sowbugs were common, as were nymphs of burrowing mayflies. Density estimates of the mayfly nymphs ranged as high as 1,500 per square meter at one station in fall 1972. Less abundant were

caddisfly larvae, snails, and fingernail clams. Overall, the bottom fauna of the river appeared to be more diverse than that in the Great Lakes.

Benthic invertebrates were sampled at 31 stations in the St. Marys River during a draw-down in November 1973. A reduction in flow of about 80% during a morphometric survey of the rapids provided an excellent opportunity to study the bottom fauna. Dominant among the invertebrates were caddisfly larvae, isopods, and crayfish. Density of caddisfly larvae ranged as high as 11,576 per square meter (average, 4,660).

Benthic organisms were collected in a shipping channel in Saginaw Bay, Lake Huron, as part of a study of possible biological effects of a proposed ice-suppression test to be conducted by the U.S. Corps of Engineers. The feasibility of using the thermal discharge of a power-generating plant to suppress ice formation over a navigation channel will be investigated. The test is part of a much larger Corps program aimed at determining the practicability of extending the navigation season in the Great Lakes. The principal taxonomic groups of benthic organisms were oligochaetes, midge

larvae, and ostracods. Seasonal changes in population density of oligochaetes and midge larvae followed a clearly defined seasonal pattern. If the proposed test has an adverse impact on the benthic fauna, a disruption in the pattern should be apparent and identifiable.

Tunison Laboratory of Fish Nutrition

Quantitative dietary requirements of the vitamins biotin and choline in reared lake trout.—Typical biotin levels in fish feeds may be as high as three times that needed. A substantial savings in fish feed costs would result from reducing the biotin content. Results obtained at the Tunison Laboratory from feeding lake trout 0.0 to 5.0 ppm of biotin suggest that the optimum level of dietary biotin is between 0.5 and 1.0 ppm of the dry diet. Feeding either higher or lower levels caused a depressed appetite, inefficient utilization of feed, and suppressed growth.

A study in progress indicates that dietary choline is essential for normal growth of young lake trout and that methylaminoethanol and dimethylaminoethanol are effective as substitutes.

INLAND FISHERY MANAGEMENT

Eastern Fish Disease Laboratory

Health and disease of freshwater fishes.—Experimental evidence supporting the hypothesis of egg transmission of Infectious Pancreatic Necrosis Virus (IPNV) has been obtained by both the Eastern Fish Disease Laboratory and the Western Fish Disease Laboratory.

Use of biochemical tests, antisera, and culture media that differentiate between bacteria or that selectively inhibit certain organisms have been employed in new and comprehensive identification procedures for clinical diagnosis of fish diseases caused by gram-negative bacteria. The scheme was worked out in collaboration with scientists from the University of Georgia. The timely work is important because of the rapidly growing concern among fish-culturists about infections caused by intestinal bacteria.

In a collaborative study with Oregon State University, specific substances were found on

the surface of the kidney disease bacterium that are peculiar to the organism and are present on all tested strains of it. The substances were precipitated chemically and separated on the basis of molecular size and electrical charge. Chemical determinations indicate that the substances are antigenic glycoproteins—combinations of carbohydrate and protein. These antigens are the most promising substances known for preparation of specific antisera and for detecting carrier fish.

Physical and biophysical methods for detecting spores of *Myxosoma cerebralis*, the whirling disease organism, were compared. In test fish with subclinical infections, the Eastern Fish Disease Laboratory's pepsin-trypsin-dextrose method proved to be 10.5 times more sensitive than examination of crushed head cartilage. The method was adapted to hatchery inspection work. A method in which a plankton centrifuge is used on ground skeletal elements has been developed at Ohio State University. Tests at

the Eastern Fish Disease Laboratory indicate that the centrifuge is effective in concentrating spores and that the method should be compared with the best biophysical method.

In an extension of earlier work, ultraviolet irradiation at 27,000 and 18,000 microwatts per second per cm² effected a 60% reduction of whirling disease infectivity. Two accidental incursions of silt interfered with irradiation and allowed a low level of infection.

Although the size and morphology of *Myxosoma cerebralis* have yet to be determined, its infectivity was found to be destroyed by a 30-minute exposure to as little as 10 parts per million chlorine.

Polypodium, a small organism related to *Hydra* and jellyfish was found to be parasitizing and killing sturgeon eggs. *Tetrahymena*, usually considered to be a free-living protozoan, was found associated with ulcerated lesions in dead and dying guppies. *Eimeria spleni* destroyed spleens of fathead minnows at the Fish-Pesticide Research Laboratory.

Using gel electrophoresis, we compared serum from several age groups of normal rainbow trout with serum of fish infected with whirling disease, but found no differences.

Antigens from spore concentrates were prepared by sonication or grinding of frozen material. Only the grinding adequately preserved antigens of the organism. Rabbit antiserum was prepared against the whirling disease organism and careful serological tests revealed that the parasite mimicked rainbow trout tissue. This example of adaptation by a parasite to its host reduces hopes for a method of serological detection.

Immune response of channel catfish.—A 3-year study of the immune response of channel catfish to two natural pathogens, a virus and a bacterium, was completed. Killed *Chondrococcus columnaris*, the bacterium, elicited measurable response within a week, and agglutination of the organism occurred at a dilution of 1:2048 at 4 weeks. A boosting inoculation produced a doubling of antibody. In contrast, live channel catfish virus was a poor antigen; some fish responded well but more than half responded poorly, and all failed to respond to a second or boosting injection of virus.



Experimental application of Thanite for collecting live fish in a shallow pond near Greenville, Ga. (Photo by Leif L. Marking)

Catfish antibodies against the two pathogens differed biochemically and biophysically. Bacterial antibody was like beta and gamma fractions of human blood. Viral antibody was not like the bacterial antibody but resembled the human alpha fraction.

Analyses of normal catfish serum and serum from immunized fish showed there were qualitative and quantitative differences in total protein and in three serum enzymes that have critical value in human disease diagnoses—lactic dehydrogenase, esterase, and acid phosphatase. Total serum proteins and esterase activity show promise for detection of virus carriers.

Red blood cells coated with virus or bacterial preparations are used to show agglutination (clumping of cells) with antiserum. Known as indirect or passive hemagglutination, the sensitive serological test has potential application in fish diagnostics. Toxin from an important fish disease, furunculosis, was coated on erythrocytes. These cells were exposed to specific rabbit serum which caused strong agglutination and to trout antiserum which gave a weaker response. The usefulness of this application is diminished because of the weak response with trout antisera.

Channel catfish sensitized by injecting bacteria and then specific antiserum showed a localized inflammatory response—indicating

hypersensitivity. This reaction, the first shown in a fish, has potential application in disease carrier detection.

Antisera for disease diagnosis.—Effective diagnosis of the bacterial and viral diseases of fish is dependent on availability of specific antiserum for each disease agent. At present there is only one diagnostic antiserum for fish sold commercially. To provide the needed sera, the Eastern Fish Disease Laboratory prepared, standardized, and distributed diagnostic antisera for furunculosis, Hagerman redmouth disease, infectious hematopoietic necrosis, and corynebacterial kidney disease.

Fish Control Laboratory

Use of Thanite for collecting live fish.—Thanite has been under study for potential development as a fish-collecting aid. Two ponds in northern Florida were treated with Thanite to obtain additional efficacy data needed to support applications for clearance and registration. Within 5 hours after an application of a 1.5-ppm concentration, live collections of largemouth bass, bluegill, warmouth, stumpknocker, lake chubsucker, golden shiner, and American eel were made. Nearly 90% of the fish collected recovered when transferred to fresh water.

Only 83 largemouth bass longer than 4 inches, of which 45 (53.2%) were captured alive, were found in the second pond. Species collected alive after the treatment included bluegill,

black crappie, red-ear sunfish, flier, bluespotted sunfish, chain pickerel, redbfin pickerel, lake chubsucker, golden shiner, and spotted gar.

Efficiency in collecting fish alive was reduced by: (1) dark water color; (2) wind-induced rippling; (3) bright reflections from broken cloud cover; and (4) the presence of numerous aquatic weeds, all of which limited or reduced visibility.

When numerous aquatic invertebrates and selected fish were exposed to Thanite in static and flow-through toxicity tests, ostracods and snails were more resistant than channel catfish or bluegills.

Samples taken from areas treated with 1.0 ppm Thanite indicated that residues of the chemical had disappeared from the mud after 4 days, from fish tissue after 7 days, and from the water after 14 days.

Registration of fishery chemicals.—High-priority chemicals were identified early in the year and efforts were begun to compile vital information on each. Preliminary status reports on 22 compounds were prepared detailing: (1) use patterns in fisheries; (2) patent positions; (3) status of current registrations; and (4) estimates of the research yet to be done to obtain registrations for fishery uses.

A concerted effort was made to develop complete literature reviews on 24 high-priority fishery chemicals. The reviews (about 98% complete) cover about 1,000 pages of highly technical information on the basis of which administrative decisions can be made as to the amount of research remaining to be done, its cost, and the likelihood of success in obtaining approval for use.

Research and liaison efforts to expedite registration of fishery chemicals involve extensive dialogue and interaction with the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA).

Investigational New Animal Drug Applications (INAD) were filed with the FDA—INAD 1361 on quinaldine sulfate, and INAD 1362 on a quinaldine sulfate:tricaine methanesulfonate combination. An application for an Experimental Use Permit was filed with the Pesticide Registration Division of EPA for the use of Thanite as a fish-collecting aid.

Declarations that use patterns of salt (sodium chloride) and lime do not constitute



Urine is collected from fish that are exposed to chemicals in confinement chambers to study the metabolism of the chemicals. (Photo by Leif L. Marking)



Fish mortalities in the waste water treatment lagoon at the Fish Control Laboratory following treatment with fish toxicants for a species assessment. Mature carp and small panfish dominated the population. (Photo by Leif L. Marking)

pesticidal or drug usage have been filed and should eliminate the need to register these compounds. Petitions for exemption from registration have been submitted to cover fishery uses of formalin and potassium permanganate.

Many chemicals have limited registrations (obtained earlier) or incomplete labels. Liaison with industry and regulatory officials has established that data are being developed on TFM (lampricide), Bayer 73 (Bayluscide), simazine, Masoten, 2,4-D, diquat, and antimycin to provide the basis for full registration. Cooperative work between the U.S. Fish and Wildlife Service and industry is under way in an effort to ensure continued progress.

Industry obtained registrations for endothall and copper sulfate and is expected to file peti-

tions for the registration of Betadine and Squoxin.

Literature reviews provided the information that registration of rotenone would be a costly, time-consuming process, involving a myriad of analytical problems. Chances of success are dependent upon results of studies by industry to prove its human safety.

Fish Farming Experimental Station

Reaction of channel catfish to water current.—Catfish in a deep vat were quickly attracted to water current, but dispersed throughout the vat after 30 minutes. Movement of the pump to the opposite end of the vat caused almost identical reactions. Fish placed in the center of a shallow trough moved towards the current and

remained in an area just below the turbulence for more than 45 minutes. Repeated moving of the pump to opposite ends of the trough resulted in attraction to the newly directed current.

Harvesting pond-raised channel catfish with trapping enclosures.—Experimental harvesting devices were tested to capture commercially feasible numbers of channel catfish from farm ponds. Catches from trapping enclosures with radii of 70, 45, and 28 feet were compared to determine if trap size was a limiting factor. The enclosures were constructed of 1-inch bar measure nylon seine hung in semicircles around demand feeders located in a 160-acre pond stocked with channel catfish. Catches in the smallest trap were significantly higher than catches in the larger traps, indicating that there is apparently no advantage in fishing larger trapping enclosures.

Trapping enclosures were fished in a 1-acre pond and in a 160-acre pond to determine what portion of the channel catfish population could be removed by this harvesting method. Two 45-foot radius traps captured 93% of the population in the 160-acre pond in 13 closures, and 82% of the catfish in the 1-acre pond in two closures. Under these test conditions the trapping enclosures proved to be effective harvesting devices for capturing channel catfish in farm ponds.

Marking of catfish with silver nitrate.—Techniques for marking catfish with commercial silver nitrate applicators are being developed for selective breeding and behavioral studies. Retention from a single tracing of the applicator was fair after 8 weeks and poor by 14 weeks. However, multiple tracings of the applicator have produced good retention for more than 8 weeks. Advantages of the method are ease and versatility of marking, low cost, and lack of effects on behavior or survival.

Recapture of channel catfish attracted to cages.—Channel catfish fingerlings (2,130) in three cages in a 4.3-acre pond were trained to associate feed availability with a tone (512 hertz) from an underwater speaker. The same number of fingerlings in three other cages were fed without the tone. Four of the six cages were closed, confining the fish, and the other two (one with a speaker and one without) were left open. A continuously operated, ultraviolet

insect-attraction light was suspended above one of the closed, speaker-equipped cages.

The fish in the closed cages were released after 34 days. After freedom in the pond for 75 to 129 days, fish that returned to the cages during feeding were trapped and removed. (The nocturnal tendencies of the fish necessitated trapping at night.) Of the total number released, 79% were recaptured in four entrapments. In August in the first entrapment, the cage with the insect light captured 684 fish (96% of the number released from that cage). Catches were not significantly different between the open and closed cages or between cages with or without speakers.

The fish were fed at the rate of 1.4% of their body weight daily. When recaptured they averaged 0.7 pound and food conversion (weight of food/weight of fish) was 1.46.

In a 4.2-acre pond with large channel catfish, grass carp, and goldfish, 710 caged channel catfish fingerlings were trained to associate feed availability with a 512-hertz tone from the underwater speaker. The caged fish were released after 30 days, and trapping began 16 days later. Of the total number of catfish, both pond-stocked and cage-stocked, 33% were captured in 16 entrapments from August to December. Only 11% of the grass carp were trapped. No goldfish were caught although there were 458 in the pond. Some of the larger catches of catfish were made at the lower water temperatures. Catfish feeding activity was observed only after sundown, even in November and December.

Use of electricity in the study and rearing of channel catfish.—Studies on the conditioning of channel catfish (6 to 16 inches total length) to a pulsating exponential-wave direct current stimulus showed that catfish can learn to avoid an electrical punishment area. Electrical currents of 24 pulses per second combined with 0.02 or 0.01 volt per inch restricted fish to 3.1 cubic feet of a 67.1-cubic foot tank.

The use of pulsating exponential-wave direct current stimuli in conjunction with a bar grader has proved effective for grading channel catfish. The grader with 1.75-inch bar spacings served as the positive electrode in this system and separated fish into two distinct size groups at a faster rate than a conventional grader. Groups of fingerling channel catfish exposed to

one of five electrical treatments (AC, continuous DC, and pulsed DC of 15, 20, and 25 pulses per second) and raised in cages for 133 days revealed that extreme electrical stress did not significantly affect fish production.

The effects of electrical stimuli on fecundity was determined when fish were exposed to pulsed DC of 0.7 and 3.8 volts per inch for three time periods of 60, 90, and 120 seconds duration. The most extreme treatment (3.8 volts per inch for 120 seconds) reduced survival but did not affect the maturity index.

The recovery time for catfish exposed to three types of electrical stimuli at five voltage levels (0.2, 0.5, 1.0, 2.0, and 4.1 volts per inch) and four time periods (30, 60, 120, and 240 seconds) showed that the average recovery time increased with voltage level and time. Fish exposed to AC had the longest average recovery time and the lowest average survival rate. Fish exposed to pulsed DC responded to touch stimuli before fish exposed to continuous DC. Internal injuries (ruptured blood vessels along the vertebral column and occasionally damaged vertebrae) were more common in fish treated with AC than in those treated with DC.

Production of channel catfish in rotation with farm crops.—A cooperative study with the University of Arkansas was initiated to examine methods of integrating fish production into farming operations. Channel catfish are being reared under two production schedules in four 3-acre ponds. Two other 3-acre ponds serve as "water only" controls and two 3-acre field plots are being used to compare production of a "typical" farming operation.

Nutrition and feeding of channel catfish and other species.—Feeds with low protein (25%) may satisfy fish growth needs during early spring and late fall when water temperatures and metabolic activity are low. However, in water at temperatures above 24° C, fish efficiently utilize feeds containing 32 to 34% protein. Feeding costs may be reduced by a "phase-feeding" program in which low-protein feeds are used when growth is restricted because of temperature.

Animal protein concentrates may be reduced or eliminated from fish feeds during periods of high metabolic activity, if total crude protein is 32 to 34%. However, the use of fish meal

and other animal protein sources in a feed lowers the total crude protein requirement to about 25 to 30%.

Growth and feed conversion for 2-year-old channel catfish was not improved by the stocking of fathead minnows in rearing ponds. Only 5% of the stomachs of fish examined during an entire summer contained minnows.

Among 3-year-old channel catfish re-stocked after October harvest and provided with an excess of forage fish, catfish fed pellets semi-weekly from November to March gained 15% in weight, whereas those not offered supplemental feed gained only 9%.

In one experiment, the cereal grain and cereal by-products components of a fish feed were removed and fed separately as a whole grain and the remainder of the formula was fed as a concentrate. This feeding arrangement did not prove economical.

Dried poultry droppings added to fish food proved to be an adequate replacement for an equivalent amount of protein.

For the third year, buffalo hybrids stocked with channel catfish have added significantly to the total pond production without decreasing catfish growth or feed conversion. To attain market size in one season, buffalo weighing about one-third pound should be stocked at the rate of about 140 per acre.

Nile tilapia (*Tilapia aurea*) stocked with channel catfish and with catfish and buffalo hybrids, are adding to total pond production without decreasing catfish growth. Tilapia stocked singly and fed a coarse meal are growing rapidly, from a stocking weight of 0.038 g at age 5 days to 30 g at age 2 months.

Sixteen percent of fresh, pasteurized grass carp added to a dry meal mixture and pelleted, then dried to 11% moisture, proved adequate to correct an unknown nutrient deficiency in brown trout.

Utilization of algae by fish.—The Nile tilapia and bigmouth buffalo grew well when fed, exclusively, fresh *Arthrospira platensis*, a blue-green algae used as human food in Chad, Africa. The food conversion of Tilapia was 1:1 (1 g of dry algae yielded 1 g of fish) and that of buffalo was 1.8:1. Grass carp did not grow well and had poor food conversion when fed

Spirogyra sp., a native green alga. Algae have potential in fish culture and might be particularly useful in providing food in the famine-struck sub-Sahara.

Production of monosex grass carp.—Monosex grass carp were produced by gynogenesis, a process whereby eggs develop after stimulation by radiation-inactivated sperm. Eleven gynogenetic grass carp remaining from 34 hatched in 1972 were tentatively identified as female. The 133 gynogenetic grass carp produced in 1973 are still immature. Yields improved in 1974 (5,700 gynogenetic fish were produced) because healthy brood stock and better techniques were used. Larger quantities of sperm, agitation during ultraviolet-irradiation, and shorter irradiation (15 minutes) all promoted gynogenesis. Exposure of eggs to relatively low temperatures (12, 14, 16, and 18° C) did not provide the improvement in yield that has been suggested in the literature.

With gynogenesis, sufficient monosex grass carp can be produced to allow testing of this exotic species in the United States without danger of permanent establishment.

Production of channel catfish in raceways.—As in past experiments, varying the water exchange rate in raceways made only small differences in growth and survival. Only at high stocking densities did low flow rates become limiting. Stocking density, however, had a dramatic effect on growth and a mild effect on survival. As stocking density increased the gross yield increased, but the mean size of fish, feed conversion efficiency, and survival all decreased. The greatest gross yield was 9-1/2 pounds of fish per cubic foot of space at a stocking density of 20 fish per cubic foot. However, this density was less efficient than lower densities in terms of profit potential because feed conversion was poor, the fish produced were small, and survival was poor.

The greatest cost of production in raceways was for fish for stocking, followed by feed, labor, and water pumping, in that order. Selective cropping of fish at 2-week intervals resulted in a more uniform product, but a lower yield, than did nonselective cropping.

Raceway culture of green sunfish.—Green sunfish fed pelleted feeds and cultured in raceways did not produce a good overall yield. However, some individual fish accepted feed

well and exhibited good growth, indicating that, with selective breeding, raceway culture of this species might become feasible.

Hydroponics as a means of nutrient utilization.—Preliminary studies indicated that water from fish ponds did not contain sufficient nutrients to support vegetables. However, the effluent from catfish raceways produced excellent crops of certain vegetables.

Use of deep well water improves winter growth of catfish.—Channel catfish of three sizes and two ages grew extremely well during the winter when supplied with 21 to 22° C water from a well 820 feet deep. This experiment indicates that year-round growth of warmwater fish can be obtained by using water from deep wells.

Container culture.—Six raceways, 25 feet long and 3 feet wide, were each partitioned into four equal compartments. Water was maintained at a depth of 2-1/4 feet in three of the raceways and 3/4 foot in the others. Inflow into each was 21 gallons per minute.

Except when expressed as production per cubic foot of water—2.1 pounds in deep water and 14.1 pounds in shallow water—depth of water did not influence fish production. Regardless of water depth, fish production in the lower compartment was less, the fish were smaller, there was less gain, and food conversion was higher.

Closed recirculating systems.—When channel catfish with an average weight of 0.3 pound were stocked at the rate of 6 per cubic foot in outdoor recirculating systems, the fish did not grow and only 88% survived after 53 days. In the same system, fish averaging 0.04 pound stocked at 2 per cubic foot, grew to a 0.17-pound average weight in 100 days.

Physiology.—There are indications that fish under very crowded conditions that are feeding well but not growing, secrete a substance or substances that are toxic to brown bullhead cells growing in tissue culture.

Fish Genetics Laboratory

Evaluation of strains of rainbow trout.—A program to systematically examine existing strains of wild and domestic rainbow trout was implemented in the summer of 1973. Each strain will be grown in the standardized rearing environment of the Fish Genetics Laboratory to

evaluate inherent production traits of the individual strains. This evaluation will be followed by field testing in hatchery and wild situations to complete the characterization of each strain. The primary goal is to provide information to the individual fishery resource manager that will help him select the rainbow trout strains best suited to a particular environmental situation. The secondary goal is to obtain information describing the genetics of rainbow trout—specifically the variability, heritability, and phenotypic and genotypic correlations of economically important traits. Some of the hatchery traits measured include egg survivability, abnormal fry, fry and fingerling survivability, fry and fingerling growth rates, feed conversion, blood chemistry, behavior, age of first maturity, adult size, and characteristics and quantity of sex products. Field testing traits include growth rate and survivability in each testing situation. The traits measured in each situation are under continual re-evaluation and will be modified as their value in strain differentiation is better understood.

The individual strains are evaluated by random selection of 50 males and 200 females mated to produce 200 families which are reared as individual families. This design will permit a detailed genetic evaluation of each trait measured. The complete evaluation for a single strain will occur over one generation in the life cycle and will take 3 to 4 years. The strains of rainbow trout on which evaluation began in 1973 or early 1974 are as follows:

Date	Strain	Source	Degree of domestication
June 73	Fish Lake	Fish Lake, Utah	Wild
Aug. 73	Shasta	Ennis National Fish Hatchery	Hatchery
Oct. 73	Manchester	Fish Genetics Laboratory	Hatchery
Jan. 74	Sand Creek	Fish Genetics Laboratory	Semiwild
Jan. 74	New Zealand	Fish Genetics Laboratory	Semiwild
Jan. 74	McConaughy	Wyoming State Fish and Game	Semiwild

Preliminary analysis of data gathered to date indicates that extremely large differences may exist between these strains in many economically important traits. Some 35 heritability

estimates have been calculated on the strains and attributes listed above.

Inbreeding and hybridization of rainbow trout.—The basic approach developed to measure inbreeding effects was to multiple-mate individual fish to produce two separate half-sib families, one of which was inbred and the other outbred. The effect of inbreeding for any particular trait is then measured as the difference between these two families. This approach was applied to 103 female and 67 male half-sib families with inbreeding coefficients of $F = 0.25$ (equivalent to one generation of brother-sister mating). The resulting inbreeding depression estimates on hatching, production of swim-up fry surviving to 147 days of age, and attained weight at 147 days of age were 4.4, 16.1, and 9.8% for female and 1.7, 22.2, and 12.0% for male families, respectively. The estimates for fry survival and attained weight were significant (99% confidence limits), but egg hatchability estimates were not. The reduction in production potential of an inbred ($F = 0.25$) lot of fish as compared with an outbred group in terms of number of fish and pounds of fish produced were 16.1 and 24.4%, respectively. These values measure only the losses which occur during the fry stage and are expected to underestimate the total losses. Similar estimates of inbreeding depression on these traits at higher levels of inbreeding indicate that the rate of depression increases with the level of inbreeding.

The magnitude of the effects of inbreeding already defined strongly suggests that serious attention should be given to finding ways to limit the rate of inbreeding accumulation in existing brood stocks. This limitation could be accomplished in a number of ways as the basic principles have already been developed by breeders of other plant and animal species. One of these methods—wide strain crosses—is presently being used at the Fish Genetics Laboratory. During the winter of 1973–74, crosses were made between males from two fall spawning rainbow trout strains and their strain hybrid with females of three spring spawning strains and two strain hybrids to produce 15 fall-spring strain crosses that should possess low levels of inbreeding. The fish exhibited several strain differences at an age of 8 months. General improvement in egg hatchability, fry

survival, and growth rate to 150 days have been found in the hybrids when compared with the pure breeding strain. Comparisons involving more than two strains do not appear to further improve egg hatchability or fry survival but do yield substantial improvement in growth rate. These families are being reared to catchable size (100 grams), at which time the evaluation of strain hybrid potential in fishery production situations can be better examined. To this point the use of strain hybrids in hatchery and commercial production looks very promising.

Development of standard population of rainbow trout.—This project, initiated in 1971, to develop two randomly breeding laboratory control populations, was completed in the spring of 1973. All unselected fish stocks maintained at this laboratory were sampled biweekly throughout the spawning season from August 1971 through March 1974. Every year these samples (each representing progeny from 20 or more parents) were reared to 1 year of age then systematically pooled to form two groups—a fall (August through mid-December) and a spring (mid-December through March) spawning population, with each containing 500 fish representing at least 200 pairs of parents. This process was repeated in the 3 years to maximize the genetic sampling of these stocks. At the end of the 1974 spawning season these two populations were declared closed, meaning that all their future generations will be derived from a fixed gene pool. These populations will be maintained by random mating and will be used to provide a constant reference population for research conducted at this laboratory. Maintained at 500 fish per year class, they are expected to serve this control function effectively (without significant effects of inbreeding or natural selection) for 20 to 30 years.

Selection study for improved growth rate.—This project was designed to determine how fast the growth rate of a spring and a fall population of rainbow trout could be improved by 147 days post fertilization. The fourth cycle of selection in both of these groups is nearing completion. During the past year 34 fall lots averaging 4.55 g and 10 spring lots averaging 4.00 g were reared to 147 days of age. Selection gain over the four selection cycles has been from 2.25 g to 4.55 g in the fall population (a

gain of 2.30 g or 102%—25.5% per selection cycle), and from 1.88 to 4.00 g in the spring population (a gain of 2.12 g or 113%—or 28.3% per selection cycle). Evidence to date indicates that selection is continuing upward and has not yet reached a plateau.

A program for field testing these fish was initiated through cooperative efforts with McNenny National Fish Hatchery, Bozeman Fish Culture Development Center, and the Wyoming State Fish and Game Department. Results from the hatchery phase of this program should become available during the fall and winter of 1974.

This selection has been prompted by the fact that a high correlation exists between growth and efficiency of food conversion. Before pursuing the study further a test of relative superiority of rapidly and slowly growing groups will be conducted under noncaptive conditions.

Cooperative studies.—This program initiated during the past year establishes a means for evaluating rainbow trout strains in hatchery and field environments where they would actually be used by the fishery resource manager. Under this program the Fish Genetics Laboratory provides eggs of particular fish strains to the cooperating agency. The cooperating agency rears the fish to plantable size and stocks them. Data on such factors as growth, feed conversion, and survivability are gathered at each stage in the program and evaluated by the two agencies.

At the present time a total of seven tests are in progress with three agencies: McNenny National Fish Hatchery, Bozeman Fish Culture Development Center, and the Wyoming Department of Fish and Game.

Southeastern Fish Cultural Laboratory

Protein sources for fish food.—Recent declines in anchovy fish meal, the primary animal protein component of channel catfish rations, have hastened the demand for plentiful, economic substitutes. Several sources of animal proteins, because of their relative amino acid composition, are potentially highly nutritive substitutes. Those with little or no value as human foods, such as by-products of the food industry, are of particular interest when bulk quantities are readily available. Accordingly, comparative tests were run with three diets—

one with bovine blood meal plus rumen contents, one with only marine fish meal as the protein component, and one with a combination of both protein sources. Catfish grew equally well on all three diets and food conversion was good.

Similarly, the waste from commercial catfish processing was tested. It is estimated that 12 million pounds per year of this material are available and not utilized. Diets were formulated with catfish waste meal (CWM) at about one, two, and three times the amount available for feed if all catfish waste were recycled back into catfish feed. Other diets having marine fish meal or vegetable (soy and peanut) protein were formulated for comparison. They had equivalent amounts of protein nitrogen and total calories of metabolizable energy. Catfish receiving the highest percentage of CWM (29%) had the best growth rate of all groups tested, and growth of fish receiving the lowest proportion of CWM was about 20% less. Thus, CWM proved to be a valuable source of animal protein for catfish.

Better economy with graded catfish.—Catfish farmers lose considerable profit yearly by “feeding out” fingerlings whose growth after one season puts them either below or above the acceptable size for batch processing. Catfish feed is costly compared with the price of fingerlings stocked at the start of the growing season, and because no compensation is made for poundage of harvested catfish that falls below acceptable weights, a simple method to preselect the usable size class is desirable. Therefore, a study was conducted wherein frequency distribution of fingerlings was compared with that of fish at harvest after 184 days. Obviously the relation between beginning weight (or length) and harvest weight may vary with such factors as diet, growing season, and pond productivity. Nevertheless, size proportionality within populations in the present study were consistent enough to insure that essentially all fingerlings between 5 and 6 inches (125 and 150 mm) long as fingerlings were of acceptable harvest size after 184 days.

Synthetic hormones in fish reproduction.—Fishery scientists in British Columbia reported successful ovulation of gravid goldfish by injections of clomiphene citrate, a synthetic estrogen that causes multiple births in mammals. They presented evidence that the mode of action

involved stimulation of the pituitary to secrete gonadotrophin which, in turn, induced ovulation. If this response were valid for many fishes, its potential use in fish culture in possibly making fish reproduction independent of normal annual cycles is of considerable interest. However attractive the possibility, pilot studies have thus far indicated that male goldfish do not respond with spermiation as females do with ovulation. Daily injections of 0.1 to 20.0 μ g clomiphene citrate/g body weight for 4 days were ineffective, whereas a single injection of carp pituitary gonadotrophin was. Further studies with females and additional observations on the gametogenic response appear to be warranted.

Tunison Laboratory of Fish Nutrition

Effects of reduction of dietary water in reared brown trout.—Because many experimental diets currently used in fish nutrition studies contain a high percentage of water, they require low-temperature storage and frequent preparation to minimize spoilage. A successful low-moisture experimental food would be more economical than most diets now used. Results of a 17-week study showed that juvenile brown trout can be fed a pelleted semipurified diet containing as little as 9.6% water, without undesirable effects on their growth or body com-



Freeze drying in a lyophilizer is the final step in preparation of Hagerman red-mouth vaccine. (Photo by D. E. Crouch)



Electrometric titrator determines physiological changes in the blood of fish following stress. (Photo by D. E. Crouch)

position, or on the conversion of dietary dry matter to fish flesh.

Amino acid supplementation of soybean meal.—Two experiments with rainbow trout were conducted to determine the influence of adding amino acids to diets containing soybean meal. Although the balance of amino acids in soybeans was improved by the supplements, optimum performance was not obtained by merely meeting minimum requirements. Apparently complex interactions between amino acids are involved.

Influence of mineral supplements in diets fed to trout.—Experiments were conducted to determine the influence of mineral supplements in diets fed to trout. Brook trout apparently could tolerate high levels (2%) of supplemental salt (NaCl), and the minimum requirement was probably less than 0.5% of the diet. When rainbow trout were fed diets containing only plant proteins, supplements of calcium phosphate were necessary to obtain optimum growth, feed conversions, and bone development.

Quantitative choline requirement of brook trout.—The commercial production of choline, a vitamin required by fish and other animals, has been reduced in the past year. In a study conducted with brook trout, the fish showed no measurable response to supplements of choline to the diet. This lack of response suggests that the low level of choline contained in the basal diet may not present a significant problem.

Western Fish Disease Laboratory

Atlas of trout histology.—Although the histology of fishes has been studied since the beginning of this century, a complete book on fish histology has never been written. The Western Fish Disease Laboratory and Oregon State University, in a cooperative project, are preparing a book on the microscopic anatomy of rainbow trout.

Vaccination tests: Hagerman redmouth disease (HRM).—To compare different methods of inducing protection against HRM, we either fed or inoculated rainbow trout with HRM vaccines in the laboratory. Antibody production and protection against disease challenge, measured at various time intervals, indicated that the inoculated fish were protected longer than the fed fish. Fish inoculated with the vaccine also had high titers of humoral antibody, whereas no antibody was detected in fish fed the vaccine. This study was repeated at two National Fish Hatcheries with similar results.

Comparison of effects of catch-and-release fishing on hatchery and wild trout.—In a joint project with the Washington Cooperative Fishery Research Unit, the physiological effects of catch-and-release fishing on hatchery *vs.* wild trout were determined by measuring changes in blood chemistry, including plasma chloride, glucose, and osmolality, following varying amounts of hooking stress (0–5 minutes) and recovery times. The response and recovery of hatchery fish was compared with that of similar wild fish from Lake Chester Morse. In general, hatchery trout showed a greater number of significant blood chemistry disturbances than did the wild fish, and required a longer time for blood values to return to prestress levels. Responses of both groups were more severe at 20° C than at 10° C. Hooking stress is characterized by hypochloremia and hyperglycemia, but there was no consistent response pattern in osmotic pressure.

Physiological evaluation of fish health.—Gaussian and nonparametric (percentile estimate and tolerance interval) statistical methods were used to estimate normal blood chemistry ranges for bicarbonate, bilirubin, calcium, hematocrit, hemoglobin, magnesium, mean cell hemoglobin concentration, osmolality, pH, and inorganic phosphorous in juvenile Shasta strain rainbow trout held under defined environmental

conditions. Blood chemistry regulatory precision and the variation of the blood acid-base balance with temperature were also evaluated.

Literature reviews for drug clearance.—Comprehensive literature reviews on Betadine, malachite green, and formalin malachite green mixtures were prepared for use in the Service's priority drug clearance efforts. Areas covered in the reviews include: history of fish-cultural use, physical and chemical properties, efficacy, toxicity, residues, application methodology, and registration status.

Physiological effects of copper sulfate (CuSO_4) and Cutrine treatments on rainbow trout.—Copper sulfate can be a useful therapeutic for fish disease control but it has only a small margin of safety in soft water. In this study, the toxic side effects of CuSO_4 treatments of rainbow trout were compared with those caused by chelated copper (Cutrine). Both chemicals caused significant blood chemistry disturbances; about 2 weeks were required for a complete recovery from a standard 1-hour treatment. Although the acute toxicity of Cutrine was less, its sublethal side effects were not significantly different from those caused by CuSO_4 treatments.

Pathophysiology of IHN virus disease in rainbow trout.—Studies were undertaken to determine the hematological and blood chemical changes in rainbow trout infected with infectious hematopoietic necrosis (IHN), a viral disease of juvenile sockeye and chinook salmon and rainbow trout. Moribund fish were compared with uninfected fish, and then the physiological status of rainbow trout was determined over a 9-day period following injection of IHN virus. The purpose was to obtain a better understanding of the disease process and to determine if clinical tests would be of diagnostic value in early identification of sick fish.

The changes in moribund fish included significant reductions in plasma, corpuscular count, hemoglobin, packed cell volume, percent neutrophils, bicarbonate, chloride, calcium, phosphorus, bilirubin, and osmolality. However, significant increases were noted in the percent immature erythrocytes, percent lymphocytes, and blood pH, and no change occurred in mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concen-



Kidney imprints and blood smears are prepared for diagnostic study of virus diseases. (Photo by W. T. Yasutake)

tration, percent total leukocytes, percent monocytes, glucose, total protein, or anterior kidney ascorbate. Necrobiotic disintegrating particles were also observed in blood smears and kidney imprints from moribund fish. No change was found in serum glutamic oxalacetic transaminase, esterase, or peptidase, but there was a large increase in the B^{24} isozyme of plasma lactic dehydrogenase (LDH). Although total serum protein was unchanged, there were specific alterations in the concentration of certain alpha globulins. Furthermore, there was a severe depletion of alkali reserve and significant alterations in acid-base and fluid balance. It was concluded that death probably resulted from a severe electrolyte and fluid imbalance caused by renal failure.

After injection of IHN virus, certain physiological changes were observed before the appearance of the exterior signs. In plasma there was a decrease in hemoglobin, packed cell volume, corpuscular count, and bicarbonate, and an increase in B^{24} LDH. As in moribund fish, LDH and acid-base imbalances were characteristic of the disease. The change in plasma B^{24} LDH was specific for IHN disease when compared with diseased trout with infectious pan-

creatic necrosis virus, *Vibrio anguillarum*, *Aeromonas salmonicida*, and redmouth bacterium. The acid-base and LDH changes occurred at 10° C but not at 18° C, indicating a possible lack of subclinical changes at the higher temperature.

In a preliminary test of the immune response of rainbow trout to IHN virus, adult fish were injected with virulent IHN and maintained for 5 days at 10° C, then held at 18° C thereafter. They developed what appeared to be specific neutralizing anti-IHN antibody within 50 days after injection. Fingerling trout were passively immunized and were protected from the disease. It was concluded that the production of IHN-neutralizing antibodies afforded protection from the disease. This finding opens the possibility for vaccination of trout against some viral diseases.

We have been working closely with a commercial trout egg producer whose brood stock was infected with IHN virus. After a period of intensive research the data indicated the virus was being transmitted from brood fish to fry by contamination of ova at the time of spawning or by contamination of fry with sex products. In an attempt to eradicate the virus without destroying the valuable brood stock the following recommendations were made: (1) isolate all brood fish from fry and egg incubation facilities; (2) disinfect all ova with an iodophor before placing them in incubator trays; (3) disinfect all ponds and equipment before introducing new fish; (4) maintain strict isolation and disinfection of all equipment and personnel caring for the fry and brood stock; and (5) remove all fish from the water supply and raise the new fry in uncontaminated water. These recommendations were followed on an experimental scale at an isolated hatchery. No virus was detected during periodic examinations of the fish during the next 3 years, and fish mortality was low. In fall 1973, no IHN virus was found in the ovarian fluid from about 550 females tested. It appears that the virus was successfully eliminated from these experimental fish.

Western Fish Nutrition Laboratory

Soybeans for fish food.—The worldwide shortage of high protein feeds, and especially the scarcity of the dry fish meals used in trout

diets, has caused renewed efforts to find alternate sources of protein. Soybean protein appears chemically the best of the readily available plant proteins. Diets high in commercial soybean meal have generally produced poor results because of the refusal of the fish to consume enough feed for satisfactory growth. The difference between the growth response and the chemical value suggested a palatability or digestibility problem. We conducted a series of experiments to determine if digestibility or palatability could be improved by processing.

Whole raw soybeans were given several different dry roasting treatments. The cooked beans were cracked, dehulled, and finely ground. We then fed the different meals to large fish in metabolism chambers to test for digestibility and available energy. The meals that showed the best results were included as 80% of the diet for feeding small rainbow trout. Other ingredients of the diet were dried brewer's yeast, vitamin and mineral supplements, and the amino acids methionine and cystine.

Rainbow trout weighing about 0.64 g (700 fish per pound) were fed all they would eat three times daily, 6 days per week. The water temperature was held constant at 15° C. The fish were weighed biweekly and records kept of growth, food consumed, and mortality.

The response of the fish fed these diets was entirely satisfactory. There was no problem getting the fish to eat the diets, and growth and food efficiency was as good or better than that obtained with commercial pelleted fish feed. Mortality was within normal limits. The response to the amino acid methionine was positive, and was especially noticeable when the soybeans did not receive optimum heat treatment. Chemical analysis of the fish carcasses showed an increase in body fat of fish fed the soybean meal. However, most of this fat was around the viscera. The extraction of part of the oil from the soybeans would probably solve this problem.

The results of these tests have suggested that the temperature and time of roasting are critical to the digestibility of soybeans by trout. A few degrees difference in final bean temperature may reduce digestibility by one-half. The results also indicate that properly processed soybeans are a satisfactory source of protein and energy for rainbow trout.

ENVIRONMENTAL IMPACT ASSESSMENT

Washington Office

Stream alteration (channelization) research program.—Stream channelization associated with flood control, drainage, and navigation projects often involves extensive modification of streams and wetlands essential to fish and wildlife, and the quality of man's environment. It is the responsibility of the Fish and Wildlife Service to give water development agencies and the public the best technical advice and recommendations so that sound and reasonable decisions can be made regarding the use of our Nation's water and related land resources. To meet this responsibility, a research program has been developed to determine the effects of stream alteration upon fish and wildlife.

The objective of the Stream Alteration Research Program is to develop methods and/or models to predict the impact of a proposed stream alteration project upon a watershed ecosystem and its associated fish and wildlife resources. Since the beginning of the program in

FY 1973, nine research contracts have been initiated to investigate various aspects of stream channelization. The studies are located in 12 States and have demonstrated that stream alteration is not a regional problem but one of national importance.

Preliminary results from the nine research projects indicate that stream alteration has a varied effect upon stream and flood plain ecosystems. For example, research conducted in Ohio indicates that channelized sections of streams have lower sport fish populations but higher fishing pressure than unaltered sections. Data analysis from intensive sampling of three sections of the St. Regis River, Mont., altered by highway construction, appears to indicate an inverse relationship between total trout biomass and the degree and newness of the alteration. Studies on the Luxapalila River, Miss., indicate differences in species diversity between altered and unaltered sections of river that can probably be attributed to habitat destruction.

MIGRATORY BIRDS

National Fish and Wildlife Laboratory

Behavior patterns of willets.—In a study of behavior patterns of breeding willets in the salt marshes of coastal Texas, data were collected on the use of the striking wing pattern as a social signal. Several previously undescribed contexts in which breeding males and females utilize wing displays were discovered. Wing displays, as well as vocalizations, serve an important function in territory advertisement and defense and are often used as the only means of communicating territory occupancy to other willets. Related sandpipers do not employ wing signals to that extent, but utilize high perches on which they are clearly visible to other individuals of the species. It is suggested that the willet wing pattern and display repertoire has evolved as a means of enhancing conspicuousness in a habitat generally lacking in high perches.

Banding studies of birds.—Most of the royal tern colonies on the Eastern Shore of Maryland were surveyed in 1973 and 1974. In

Virginia the breeding population dropped approximately 50% in 1974, but such fluctuations are probably normal. Nearly 5,000 young terns and 250 adults were banded in the 2 years as part of a study of population structure and survivorship. Twenty-two previously banded birds, ranging from 8 to 17 years of age, were also trapped. These recaptures provide the first information on age of breeding in royal terns and add new information on longevity for the species.

Nearly 4,000 seabirds of various species were banded in a continuing study of population dynamics of marine birds on the Pacific Phoenix Islands. Numerous recoveries of previously banded birds as old as 16 years were made.

Molt in Wilson's phalaropes.—Specimens of Wilson's phalaropes collected during the summer at Chase Lake National Wildlife Refuge, N. Dak., were compared with wintering specimens collected in Argentina between November and January to clarify the molt cycles of adults and young. Both age classes undergo a nearly



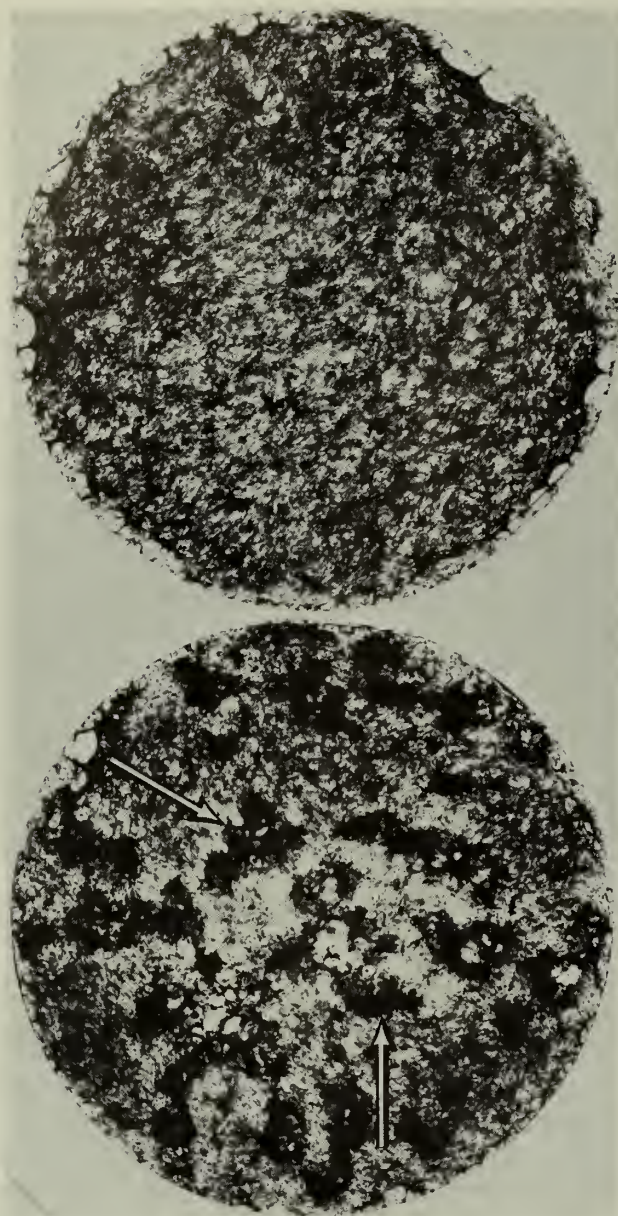
The striking wing pattern of the willet is important in territory advertisement and defense. (Photo by Marshall Howe)

complete body molt in late summer and adults molt most of the tail feathers at that time. Molt of the primaries and secondaries begins on the wintering grounds and is nearly complete in both adults and young by the end of January. Previously, ornithologists believed that young did not molt the flight feathers until after their first breeding season.

Habitat and territory of McCown's longspur.—McCown's longspur was chosen as an indicator species of the shortgrass prairie because it is totally restricted to that plant association. For a study of habitat and space requirements of this species, territories of each male on a 62-acre study plot were mapped and measured periodically through the 1974 breeding season. Preliminary results show that territory size and location vary little among individual birds during the portion of the nesting season investigated. However, the types of displays used to advertise and defend territories change over

time and territorial males habituate to displays of neighboring birds. Nests are usually positioned immediately northeast of small forbs, allowing protection from the hot afternoon sun. After fledging, the brood is divided between the male and female parents and young remain dependent upon parental care for at least 2 weeks. The period of female participation in this phase is considerably shorter than that of the male, allowing her to begin laying a second clutch as soon as possible. During very dry periods cow tanks are used extensively as a water source, suggesting that the presence of such sources may increase reproductive success in dry years.

New bird species.—A new species of tanager collected in Peru was described and named *Hemispingus parodii*, Parodi's Tanager. The species is apparently confined to montane areas between 10,500 and 11,500 feet elevation in the northern Cordillera Vilcabamba of Peru, where



The effects of duck virus on cultured duck cells. Uninfected cells are shown in the upper figure. Virus infection results in localized contraction and is seen as dark blotches indicated by the arrows in the lower figure.

it apparently restricts a closely related congener to lower elevations.

Eastern Fish Disease Laboratory

Duck Viral Enteritis.—An unprecedented outbreak of Duck Viral Enteritis (DVE) in early 1973 on the Lake Andes National Wildlife Refuge, S. Dak., killed more than 40,000 ducks

and geese. At that time, the Fish and Wildlife Service had neither the virological experience nor the legal authority to work with the causal virus; consequently weeks elapsed before university and Department of Agriculture findings conclusively established the cause. Several months later, the Department of Agriculture provided the Eastern Fish Disease Laboratory with reference virus, antiserum, and authorization for research. The ensuing work showed that a culture line of duck embryo cells was susceptible to DVE virus and that virus could be isolated and identified within 72 hours. We also found that DVE virus was killed within 36 hours by simply drying or by less than a minute's exposure to 10 ppm of chlorine disinfectant. Under conditions which simulated winter, laboratory tests additionally showed that DVE virus survived for at least 2 months in Lake Andes water. The virus could not be recovered from drained bottom muck samples taken several months after the outbreak.

The new procedures have provided valuable information for practical use under field conditions. Furthermore, diagnostic methods were taught to one Canadian biologist and seven fish hatchery biologists during a week-long workshop at the Eastern Fish Disease Laboratory. As a result, five diagnostic laboratories are now capable of handling DVE specimens and one laboratory is actively engaged in DVE research.

Migratory Bird and Habitat Research Laboratory

Waterfowl breeding-pair survey evaluated.—This aerial survey became operational in 1955 and covers most of the important duck breeding areas in North America. Its primary purpose is to measure the annual abundance of different species of ducks during the breeding season. Results of this survey play a key role in establishing duck hunting regulations each year. Because of the importance of this survey, a contract study was completed in 1974 to assess its reliability and to evaluate ways in which it could be improved to provide maximum precision at lowest cost. Results include recommendations for a larger and more representative system of air:ground visibility measurements and some changes in survey boundaries. Different counting procedures also were recommended and suggestions were made for

optimum allocation of sampling units to improve population estimates for different species of ducks.

Aerial photography tested on diving ducks.—

Very large rafts of diving ducks concentrate during the winter on Chesapeake Bay and similar bodies of water, making it difficult to obtain reliable counts of abundance. Fairly precise information on wintering canvasbacks is needed to evaluate response of this species to management practices designed to increase its numbers. For this reason, a study was conducted in 1974 to determine the feasibility of utilizing aerial photography to measure species and sex composition of diving ducks. Photographs of ducks were taken at various altitudes in color and black and white. An image scale of 1:1,000 was necessary for positive discrimination between canvasbacks and scaup. The images were identified and counted by a General Electric Multispectral Information Extraction System. All canvasbacks of each sex were correctly identified and counted. However, some male scaup were identified as female canvasbacks and some female scaup were not identified as ducks because of their comparatively dark plumage. Additional research is planned to improve the technique because of its potential as a means of eliminating human errors associated with censusing large flocks of ducks and other birds.

Canvasback food habits change on Chesapeake Bay.—Chesapeake Bay is a key wintering ground for the canvasback, a highly esteemed duck that is declining in abundance. Service biologists are conducting studies to determine if habitat conditions on the Bay are contributing to the decline in canvasback numbers. Due to the size and complexity of this major estuary, it will take several years to complete the research. However, preliminary work has shown that canvasbacks concentrate in areas where the brackish water clam (*Rangia cuneata*) is abundant. In some locations, as many as 370 clams are packed into an area of only 1 square foot. This mollusk was not reported as a canvasback food 15 years ago, when Service biologists last made a detailed waterfowl study on Chesapeake Bay. In contrast, this clam now is a major food of canvasbacks in low salinity areas. Apparently, as vegetation declined in the Bay due to increased turbidity, the clam increased



In recent years a hard-shell clam known as *Rangia cuneata* has been common in many brackish waters of the Chesapeake Bay and its tributaries. Based on food habit analysis, this clam is important in the diets of canvasbacks and scaups. (Photo by Matthew C. Perry)

in both distribution and abundance. Canvasbacks changed their diet accordingly. Thousands of canvasbacks were weighed in many different locations and there was no indication that birds were underweight. Canvasbacks seem to be getting enough food, but the variety is much reduced from earlier years and the food is concentrated in polluted areas. A decline in abundance of small clams in the future could be catastrophic to the canvasback and other diving ducks. Of equal concern is the fact that clams can assimilate and store toxic heavy metals which often accumulate in polluted waters. Plans are under way to measure contamination in this important canvasback food.

Canvasback movements studied.—Banding, color-marking with dyes, and radio telemetry were employed to learn more about the movements and distribution of canvasbacks in Chesapeake Bay and its tributaries. Wintering canvasbacks are highly mobile, but they also have a strong attachment to certain areas in the Bay. Some color-marked birds dispersed long distances from the area where they were

marked, but most birds remained throughout the winter in a selected portion of the Bay. The fidelity of the birds to particular wintering locations in the Bay was also determined from banding records; recaptured banded birds frequently had been banded in earlier years in the same general area. Although considerable information on local movements was gathered by means of radio telemetry, it was apparent that the transmitter harness caused abnormal behavior of instrumented birds. Nevertheless, testing of a better radio package will be con-

tinued because of the potential of telemetry in providing insight on nighttime activities of canvasbacks.

Range extension noted in gadwalls.—A recently completed study has documented the response of the gadwall duck to newly impounded waters along the east coast. A disjunct breeding population of gadwalls in eastern North America was first recorded in 1939. This population has extended its range during recent years and now breeds in more than 30 locations (primarily National Wildlife Refuges and Wildlife Management Areas) along the Atlantic coast from Prince Edward Island to South Carolina. These locations are 1,000 to 1,200 miles from the main breeding range of the gadwall in the central and western prairies of Canada and the United States. Approximately 40,000 gadwalls were harvested in the northern portion of the Atlantic Flyway between 1969 and 1970. The impoundment of water seems to be responsible for the range extension; they are focal points for nesting activities.

Progress in measuring survival of banded birds.—Knowledge of annual survival rates is an important tool in management of migratory birds. Advanced mathematical methods for measuring survival were developed recently as the result of contract research involving Service scientists. These new techniques make it possible to estimate survival rates and measure their statistical variation with considerably more precision than in the past. Computer programs have been developed to allow easy use of the methods by biologists working on population dynamics of various species.

Steel shot tested by duck hunters.—Controlled field tests were conducted on one Federal and four State waterfowl hunting areas in 1973 to compare the performance of number 4 steel shot (1-1/8 ounces) with number 4 lead shot (1-1/4 ounces) in 12-gauge shotguns. Hunters who volunteered for the test had no knowledge of the type of shot they used. They were accompanied by observers who recorded the number of shots fired, ducks dropped, and ducks lost. In 146 hunts wherein steel was used, 3,012 shots were fired to drop 746 ducks, of which 142 were not retrieved. In 149 hunts in which lead was used, 2,970 shots were fired to drop 734 ducks, of which 130 were not retrieved. The shot types were equally effective in dropping



The replacement of lead shot with a nontoxic substitute will save thousands of waterfowl from lead poisoning. Lead shot erodes in the gizzard of a duck (top), paralysis sets in, the gizzard becomes impacted, and the duck succumbs to poisoning and starvation (bottom). (Photos by Fred B. Sampson)



Banding a mallard duck. New mathematical techniques for estimating survival rates will improve management of migratory birds. (Photo by Matthew C. Perry)

ducks. The higher rate of loss with steel (steel, 19.0%; lead, 17.7%) was not statistically significant.

Reward bands aid in mallard population studies.—There is an important need to determine the proportion of the waterfowl population harvested each hunting season; this information makes it possible to measure the effectiveness of different hunting regulations, and it is useful in assessing population status of different waterfowl species. For many years, the first-hunting-season recovery rate of banded samples was used to measure rate of harvest. However, it is known that hunters do not report bands from all marked birds that they bag, and the tendency of hunters to report banded birds may vary in different areas. Consequently, an adjustment is needed to account for the band-

reporting rate (proportion of retrieved bands reported to the Bird Banding Laboratory).

A recent study provided this much-needed information for the mallard, the most important North American duck, both in terms of abundance and harvest. This 2-year study was begun in 1972 and was based upon use of regular leg bands and bands with an inscription indicating a \$10 reward for their retrieval. During the research 2,122 immature mallards were marked with reward bands and another 11,490 immatures were marked with regular bands. Bands were applied at 74 locations in 16 States, 4 Provinces, and the Northwest Territories. During 1972, 18.37% of the reward bands was submitted to the Bird Banding Laboratory; and during 1973, 18.39% of the reward bands was reported. In contrast, the recovery rate of regular bands during the 2 years was 8.10% in 1972 and 9.19% in 1973.

Results of the study show quite consistently that hunters near a banding site do not report bands as readily as hunters 50 miles or more from the banding site. This appears to be a universal trait of hunters in locations where large banding programs have been conducted for a number of years. The band-reporting rate may vary from as low as 17% at the banding site to as high as 60% at a distance greater than 50 miles away. The data are confounded to some extent because of band collecting activities by personnel in conservation agencies. It appears that future harvest rates should be determined from band recoveries that are adjusted both for distance reported from the banding site and who reported the band (i.e., the hunter or an employee of a conservation agency).

Crippling losses of ducks measured.—A recently completed summarization of data collected through observations of waterfowl hunters from 1965–72 showed that 17.6% of 20,087 ducks shot down was not retrieved. Wood ducks were lost at a rate of 25.3%, a significantly higher loss than for any other species of duck. Except for wood ducks, there was no significant difference in loss rates among species. However, under the new point-system bag limit, the loss of 90-point female mallards (21.5%) was significantly higher than that of male mallards (15.4%) which had an assigned value of only 20 points. These results suggest,

therefore, that waterfowl loss rates may be influenced by hunting regulations.

Woodcock singing behavior studied.—Each spring, counts of calling male woodcock are made at dusk on hundreds of survey routes located throughout eastern North America. Numbers of birds heard calling per route are used as indices of abundance and are the principal basis for assessing woodcock population status. Unfortunately, the breeding behavior of male woodcock is poorly understood and reliability of the spring survey is not known. A 2-year study recently completed at a Maine field station has provided new insight on this subject. Singing by males evidently is regulated by a complex social system. Some males appear to dominate calling in others. The net result is that some males do not give the characteristic call (“peent”) at all unless a singing ground is vacated by the dominant male. Consequently, it seems clear that survey counts do not measure all males actually present in the population. Preliminary findings in Maine and elsewhere suggest, however, that about the same percentage of males may sing regardless of population size. If this is the case, then the counts serve as a valid index of annual changes in numbers of males. Additional research is planned to evaluate reliability of the singing-ground survey as a means of determining population status of this increasingly important game bird.

Mourning dove crippling loss studied.—Reliable information has been lacking on the proportion of the mourning dove population lost as a result of crippling during the hunting season. To obtain insight on this question, a pilot study was conducted during the first part of the 1973 dove hunting season in South Carolina. Two biologists obtained the information while posing as hunters. A crippling loss of 31.7% of the total estimated kill was observed. Sixty-three percent of this loss was birds knocked down within 200 feet of hunters but not retrieved. All remaining crippled birds were observed to fall at greater distances. No doubt, some additional birds also were lost even though their flight behavior did not indicate that they were badly hit. However, doves can survive results of being shot. A fluoroscopy study at the same location in the following spring showed that 6% of a randomly trapped sample of 102



A light-weight radio transmitter was fastened on this male mourning dove to obtain breeding information on doves at the Carolina Sandhills National Wildlife Refuge. (Photo by Matthew C. Perry)

adult doves carried body shot in their tissues without showing apparent adverse effects. Further research is planned to measure annual variability in observed crippling loss.

Accelerated research continues.—The Migratory Bird and Habitat Research Laboratory currently administers special funds to State conservation agencies and universities for research on shore and upland migratory birds. The Accelerated Research Program was begun in 1968 to obtain information needed for more effective management. In 1973, 34 different studies were under way in 29 States from funds provided by the program. Species studied included band-tailed pigeons, clapper rails, mourning doves, common snipe, and woodcock. Types of research varied; for example, one study focused on the population dynamics of an island population of woodcock, and another study dealt with breeding biology of mourning doves in relation to call-count censuses. This special research program has expanded work on “webless” game birds, and much new information has been obtained.

Work expands on breeding-bird survey.—Further development of the North American breeding-bird survey continued in 1974. Coverage was extended northward into British Columbia, Labrador, and Newfoundland. Coverage in the western States also is being improved. In spring 1973, 1,765 routes were

surveyed and 1.5 million birds were counted. Although most bird populations remained fairly constant in their abundance on a continent-wide basis, several species are undergoing changes. Other species show gradual long-term trends or sharp short-term fluctuations. For example, the starling (originally imported from Europe into the eastern United States) has spread to much of the western third of the continent and has increased at a rate of 22% per year from 1968 to 1973. In the east, the cattle egret, an African bird that spread into the United States from South America, increased 11% per year from 1966 to 1973.

Ospreys counted in Chesapeake Bay and the Carolinas.—A complete aerial survey of breeding ospreys in Chesapeake Bay, combined with a ground count of 70% of the birds, provided the first estimate of total size of the population. The 1973 population was estimated at 1,450 pairs. Only 31% of the birds nested in trees; the remainder utilized duck blinds (29%), channel markers (22%), and other manmade



An immature cattle egret. This species recently reached the United States from South America and is increasing in numbers and range. (Photo by John W. DeGrazio)

structures (18%). A similar survey conducted along the coastal portions of North and South Carolina yielded an estimate of 552 pairs of ospreys. Ospreys nested primarily in trees (96%) along this portion of the coast. Major concentrations of ospreys in the Carolinas occurred where fresh water has been impounded. The distribution of ospreys must have changed over the years as a result of creation of man-made nesting structures and impoundments. There was limited evidence that birds nesting on over-water man-made sites were more successful than those nesting in trees.

Habitat found important for red-shouldered hawks.—A breeding population of red-shouldered hawks along the Patuxent River in central Maryland was studied during 1943–74. The numbers of breeding pairs remained unchanged or increased on two study areas where habitat was not altered—the Patuxent Wildlife Research Center and an adjoining area. A reduction in breeding pairs occurred on the third study area where large portions of the habitat had been destroyed. Basic information on 74 nests was obtained and the annual number of breeding pairs on the Wildlife Research Center ranged from a low of four to a high of nine during the study. Nesting success of this highly territorial species decreased significantly as the distance between adjacent nest sites decreased. Since 1960, the recruitment rate during “high” density years was 1.34 young fledged per pair as opposed to 1.95 during “optimum” (1943 and 1947 levels) density years. The 1.95 figure compared favorably with the estimated recruitment rate necessary for maintaining a stable population and with recruitment rates observed in other locations prior to the modern pesticide era. As the observed recruitment rate during the 4 years of “optimum” density was believed adequate, it is doubtful that the relatively low pesticide levels in the eggs had a detrimental effect on the reproductive performance of the population.

Studies made of ways to save oiled birds.—Aquatic birds near large cities and along commercial waterways frequently have their plumage fouled by spilled petroleum products. In the past, only a small percentage of these oiled birds could be saved. Petroleum solvents are required to remove heavy crude oil and Bunker C oil because detergents are ineffective.



Duck blinds are favorite nesting sites of ospreys in the Chesapeake Bay. (Photo by Stan Weimeyer)

Unfortunately, these solvents are toxic and many birds die during the cleaning process. Detergents are not toxic to birds and can be used to remove light crude oil from their feathers. However, all detergents tested thus far that are effective in removing oil have a surfactant (wetting agent) which clings to the feathers. Consequently, birds that are returned to the water become soaked because their feathers do not repel water. Further research is planned by the U.S. Fish and Wildlife Service to develop more effective methods to clean oiled birds and to increase their survival.

Northern Prairie Wildlife Research Center

Salinity characteristics of prairie potholes in east-central North Dakota.—Seasonal wetlands contained lower salt contents than more permanent ponds. Lakes located in stagnation moraines at higher elevations were lower in salt content than those located in the outwash plain at lower elevations. The higher elevations and the resulting ground water regime associated with stagnation moraines result in ground water flow both into and out of the lake basins, consequently retarding salt accumulation. Within the stagnation moraine, lakes at lower elevations that served as sumps contained the maximum salt content; however, not all lakes in the outwash contained a high salt content. These differences may be explained as follows: Wetlands with a net seepage inflow or a high degree of inflow tend to be more saline than wetlands with a net seepage outflow or low degree of seepage inflow.

The majority of lakes that contained a high salt content were shallow, often less than 3.3 feet in depth. An exception was Lake George which had a high specific conductance and a depth of at least 92 feet.

North Dakota wood duck population expands.—In 1968 a “gentle” release of about 250 juvenile wood ducks was made on Arrowwood National Wildlife Refuge, where no previous records of wood duck breeding were known. Nest houses were installed at first within 2.5 miles of the release site, but additions in later years increased the distance to 6 miles. The introduction of wood ducks resulted in the establishment of a breeding population that uses the nest houses. Migrational homing of ducks released in 1968 accounted for 16 nests on the



At present, oil-soaked birds have little chance of survival after treatment. Research is underway to develop methods of salvaging them. (Photo by Matthew C. Perry)

Refuge in 1969. Survival and homing by yearlings from the 1969 nests and previously released ducks, increased nests to 34 in 1970. Nests continued to increase to 40 in 1971, 44 in 1972, and 64 in 1973. In the same 5-year sequence, the estimated number of young leaving nest houses was 175, 311, 417, 476, and 611. The average brood size was 11.9; nesting success averaged 84%; and no evidence of nest predation was detected.

Poor canvasback reproduction on the Minnedosa Study Area.—Spring drought conditions prevailed across prime canvasback breeding habitat in southwestern Manitoba in 1973. Pond numbers and water levels were significantly below previous years. In many ponds, emergent vegetation was stranded on dry ground. Habitat deterioration resulted in a limited number of ponds with adequate emergent vegetation required by overwater nesting waterfowl, and this contributed to a near failure in canvasback production.

Although the number of breeding pairs in 1973 (6.0 per square mile) was equivalent to those of several recent years, the number of broods (0.6 per square mile) was the lowest since studies were begun in 1962. Nesting success was 2.7% with eggs hatching in only 3 of



Canvasback hen nesting in cattails. The species nests in emergent vegetation over water. During drought habitat deterioration contributes to low nesting success. (Photo by David Trauger)

the 111 nests under observation. The 10-year mean was 41%. Predation and desertion of nests were considerably higher than in previous years. Only 5 canvasback broods were found during an intensive ground and aerial survey of 90 square miles.

Marked female canvasbacks demonstrated a strong propensity to return to the study area. In spite of the drought conditions, 75% of the adult female canvasbacks returned to their former breeding areas and 24% of the yearling females returned to their natal areas. Adult females made persistent nesting attempts but few nests reached the incubation stage. Of five marked adults studied intensively, two females re-nested at least once and three females re-nested a minimum of twice. Only two re-nestings proceeded to the incubation stage before being terminated; the other re-nesting attempts ceased when the nests were destroyed or deserted before laying was completed. No nests were found attended by the twelve marked yearling female canvasbacks but behavior patterns of a few suggested that they may have attempted to nest. Yearling females exhibited a weaker nesting drive than adult females. Whether this pattern

was related to the deteriorating habitat conditions or the innate reproductive abilities of the canvasback is yet to be determined.

Late laying by yearling gadwalls.—Ovaries and bursae of Fabricius of wild gadwall hens collected between 4 and 25 June indicated that yearling gadwalls begin nesting later than older gadwall hens. Bursa weights were used to establish the age of these hens.

Studies of mallards have shown that the bursa continues to regress in first-year birds through the breeding season and fully regressed weights are not attained until September. Preserved bursa weights of hand-reared wild mallard females declined from 267 mg in March, to 166 mg in April, to 80 mg after 3 eggs had been laid; September to December bursa weights for yearling females averaged 23.7 mg. Bursae from gadwall hens were weighed (in milligrams) and the weights divided by the bird's body weight (in grams) for comparison with previously obtained relative bursa weights for the mallard. Relative bursa weights for the gadwall hens were 94 for one bird that had not laid, 53 (range, 49–57) for four presumed yearling hens laying or just starting to incubate, and 23 (range, 12–32) for six presumed older hens laying or just starting to incubate. These compare with values of 168 for wild mallards in April, 76 for laying mallards, 58 for mallards starting to incubate, and 21 for mallards in the second fall.

Determination of the number and size of pre- and post-ovulatory follicles enabled estimation of the time that the clutch was begun. The start of laying by the six gadwall hens judged to be 2 or more years old ranged from 25 May to 10 June although there was some indication that the hen starting on the latter date may have laid a previous clutch. The mean incubation date was 1 or 3 June, depending on inclusion of the latter bird. This compares with a nest initiation date range of 6–14 June (mean of 11 June) for the four birds believed to be yearlings. In addition, the presumed yearling bird which had not laid when collected on 8 June would not have laid until 14 June at the earliest.

Social behavior of the gadwall.—The social behavior of gadwalls on the breeding grounds in North Dakota was studied in 1972 and 1973. During the spring arrival period, intraspecific aggression was limited to threat postures by

paired males and avoidance responses by other birds. Spring courtship flights occurred when paired hens were harassed by unpaired males displaying to them.

During the prenesting period the degree of intraspecific tolerance exhibited by mated drakes steadily decreased. The Chin-lift posture was the most important indication of aggressive tendencies in a mated drake. Pairs were tolerated by mated drakes to within about 20 to 30 yards in the early prenesting period but were chased when they approached to within 50 to 60 yards or flew overhead as his hen neared laying. The intensity and length of three-bird chases also increased as the nesting period approached. Male to male aggression was a common characteristic of three-bird flights.

Results of time budget analysis show that paired females spent 17 and 48% more time feeding than did their mates during the time they were together in the prenesting and laying periods, respectively. Food sources in small wetlands vary in abundance and kind owing to physical and chemical properties of each wetland. Thus, once a paired female selects an area for feeding, it could be advantageous for her mate to expel other gadwalls from the area. She could then build up her metabolic reserves for nesting with a minimum of disturbance.

Feeding ecology of blue-winged teal.—The feeding ecology of blue-winged teal was investigated on the prairie pothole area of south-central North Dakota to identify factors influencing food selection by breeding birds. Blue-winged teal that arrived early on the breeding grounds consumed a diet consisting of 55% seeds. The proportion of animal (invertebrates) foods in the diet rapidly increased to 95% by the onset of nesting in mid-May.

The invertebrate foods selected at any given time was influenced by the physical capabilities of the bird, the bird's feeding behavior, the behavior of each invertebrate species, the relative abundance of each species, the habitat occupied by the invertebrate, and the general quality of the wetland. The food selected on any given wetland type was determined primarily by the feeding behavior of the bird and the behavior of the invertebrate which interacted to influence availability. Feeding behavior was often modified significantly when invertebrates within

the aquatic habitat suddenly became highly available.

Temporary and seasonal wetlands provided ideal feeding sites in terms of abundance and availability of high protein foods during the spring and early summer months. Later in the summer, when insects began to emerge on the more permanent lakes and seasonal wetlands began to dry, feeding intensity shifted to the more permanent waters. This trend was often temporarily reversed following heavy early summer precipitation that refilled shallow water areas and stimulated invertebrate development.

Agricultural practices on the prairies favor drainage of temporary and seasonal wetlands into drainage systems or into wetlands located at lower elevations and, as a result, deep and permanent lakes are produced. This practice is altering the balanced wetland complex of the prairies by increasing the proportion of larger and more permanent water areas.

Giant Canada goose restoration in North Dakota.—In spring and summer 1973, 1,129 giant Canada geese were released at five North Dakota locations. In 1972, the first year of the 5-year experimental restoration program, 885 geese were released at four locations.

Of the 1,129 geese released in 1973, 129 were 2-year-old birds hatched at Sand Lake National Wildlife Refuge in 1971 and held there until March 1973 when they were released at Des Lacs National Wildlife Refuge, Ward County. The remaining 1,000 geese were reared in 1973 and released in groups of 250 each at the following four locations: (1) Lake Ilo National Wildlife Refuge, Dunn County, (2) a private area southwest of Gackle, Logan County, (3) Florence Lake National Wildlife Refuge, Burleigh County, and (4) Lake Zahl National Wildlife Refuge, Williams County. The Lake Ilo and Florence Lake releases were of 40- to 45-day-old birds, and those released at Logan County and Lake Zahl were 55 to 62 days of age. Known mortality was 113 geese (10%) in the 1973 releases and 211 (24%) in the 1972 releases.

A total of 181 (24%) of the 742 geese in the three main 1972 releases were observed in North Dakota during 1973 as follows: Chase Lake, 74; Robinson, 65; Long Lake, 42. Band recoveries and sightings of 1972 and 1973 released geese have come from North Dakota,



The mink frequents freshwater habitats. In a North Dakota study, the species fed mostly on birds, among which coots were predominant. (Photo by Leo M. Kirsch)

South Dakota, Nebraska, Kansas, Oklahoma, Wyoming, Colorado, Texas, and Montana.

Mink food habits on prairie wetlands.—A study of mink food habits during the waterfowl breeding season was conducted on prairie wetlands in North Dakota during 1972–73. Emphasis was on determining the minimum number of waterfowl (including American coots and grebes) and other selected prey consumed per mink family and, where possible, relating these findings to prey abundance. Six families of mink were studied intensively. Dens occupied by the mink were visited regularly; food remains and scats were collected and examined to determine the number of prey represented.

A total of 68 dens were examined, all of which were on the perimeters of semipermanent wetlands. Thirty-one vertebrate and one invertebrate prey species were identified in the food remains and scats. Avian species accounted for 78% of the vertebrate prey; all age groups were represented but most were juveniles. Waterfowl were the predominant avian prey with an average of 84 coots, 13 ducks, and 6 grebes consumed per mink family. All species of ducks commonly nesting in the area were represented in the food remains; 33% of the adult dabblers and 78% of the adult divers were females. The difference in sex composition between the two groups of prey was attributed to difference in nesting habits.



The ferruginous hawk is a large prairie buteo which often nests on the ground. (Photo by John T. Lokemoen)

Many questions remain regarding mink-waterfowl relationships but the results of this study suggest that mink may have a significant influence on the production of waterfowl on some wetlands.

Poor duck production on annually cultivated lands.—Four consecutive years of poor duck production have been recorded on the cultivated portion of a 5-square mile area near Woodworth, N. Dak. The cultivation (84% of the area) has been summer fallowed or seeded to small grain crops each year. The noncultivated portion of the area included wetlands and their shoreline fringes (12%), heavily grazed pastures (2%), shelterbelts and wooded farmyards (1%), road rights-of-way (1%), and idle grasslands (< 1%).

During four nesting seasons 5,829 acres of cultivated lands and 435 acres of noncultivated lands were searched for nests. Two (5%) of 41 nests found on the cultivated lands and eight (17%) of 48 nests found on noncultivated lands hatched. These data indicate the importance of preserving noncultivated portions of intensively farmed areas in the prairie pothole region.

The poor production of ducks on these cultivated lands is an example of the influence that the combination of tillage practices and natural predation (mammals and birds) can have on

wild nesting ducks. In almost equal proportions, farming operations and natural predation were the principal causes of nest failure on cultivated lands. Natural predation was the principal cause of nest failure on noncultivated lands.

Unmowed cover improves duck production.—Duck production in unmowed cover was 1.9 times that in mowed cover on an Interstate Highway right-of-way during the 1969–72 period. This reflected primarily the distribution of 451 nests, 64% of which were found in the unmowed half of a 23-mile segment of I-94 in Stutsman County, N. Dak. The proportion of nests found in the unmowed cover was highest for mallards (85%); pintails (81%) and gadwalls (69%) were also high. The distribution of blue-winged teal and shovelers was nearly equal in the two covers. The nearly equal proportions of the nests in the two covers that hatched indicated the distribution was probably a reflection of preference for residual cover, especially by the early-nesting species.

Nesting ecology of raptors in South Dakota.—During 1973, a study of the nesting ecology of ferruginous hawks and other raptors was conducted on a 104-square-mile area in north-central South Dakota. The study area was located in the Coteau du Missouri, a rolling glaciated region of prairie rangeland and crop-



Black guillemots loafing near their nest sites on Alaska's Arctic coast. (Photo by James C. Bartonek)

land interspersed with numerous wetlands. During an intensive survey in late April and May, 16 ferruginous hawk nests, 2 Swainson's hawk nests, 1 red-tailed hawk nest, and 1 great horned owl nest were found. There was evidence that five pairs of marsh hawks and one pair of burrowing owls also nested on the study area.

Ferruginous hawks arrived on the area in late March and early April. Nest building began soon after arrival and egg laying began during mid-April. Most clutches hatched during the third week in May and some young were making short flights by late June. Nests were built on prominent physical features with nine ferruginous nests on ground elevations, five in trees, and two on haystacks. All nests of Swainson's and red-tailed hawks, and of great horned owls were in trees.

Ferruginous nests occurred at a density of one per 6.5 square miles. Raptor nests were located throughout the study area but six ferruginous hawk nests and one red-tailed hawk nest were concentrated in a 12-square-mile zone which contained the largest continuous block of prairie. All ferruginous nests were located on prairie or close to prairie whereas both Swainson's hawk nests were built in cultivated areas.

Birds of the Bering Sea pack ice.—In February and March a Service biologist made observations of birds in the Bering Sea pack ice while aboard the U.S. Coast Guard icebreaker "Staten Island." The primary area of operations was between St. Matthew and St. Lawrence islands. Black guillemots and murres were the only species seen commonly deep in the pack ice; single birds or small flocks were

observed in most of the leads and polynias. Four species of gull were equally common in the brash ice at the southern edge of the pack ice: ivory, slaty-backed, glaucous-winged, and glaucous gulls. The ivory gull spends the year at the edge of the pack ice, breeding north of 70° north latitude. The slaty-backed gull is an Asian species that is only a vagrant in North America but it apparently is regular in the Bering Sea pack ice in winter. Both the glaucous-winged and glaucous gulls are common breeders in Alaska and some individuals will winter as far north as open water permits.

Birds present in leads and polynias deep in the pack ice face the danger of being unable to find open water. Severe cold can cause leads and polynias to freeze over and when coupled with a lack of wind no new areas of open water develop.

Black guillemots breeding in northern Alaska.—Service biologists in cooperation with personnel from the Smithsonian Institution discovered 17 black guillemot nests in northern Alaska in 1972. Until this discovery black guillemots were not thought to be regular breeders in extreme northern Alaska because the rock cliffs which guillemots usually use for nest sites are lacking. Eleven of the 17 nests discovered were under manmade debris that had washed up on the barrier islands in the Chukchi and Beaufort seas. Five nests were in a driftwood pile and a single nest was found in a cavity in a sand dune. Young were produced only from nests under manmade debris. Nests in natural cavities were apparently too exposed to avian predators and humans to allow successful nesting to take place.

These observations show that the black guillemot is adaptable enough to extend its range to areas where no rock cliffs are present. The cavities available under manmade debris are apparently of importance in this range expansion. The recent human activity in northern Alaska has provided a source of nest sites that can be expected to increase in future years.

Feeding habits of the ivory gull.—Service biologists are investigating the feeding habits of the ivory gull. The ivory gull is a high arctic species that is associated with the edge of the pack ice throughout the year. In the past, ornithologists assumed that because the ivory gull was found primarily next to the pack ice

and rarely sits in the water that it fed on the feces and carcasses of pack ice mammals. Observations made in the Bering and Chukchi seas show that there is little association between the ivory gull and pack ice mammals. On the basis of stomach contents and observations of feeding behavior, the ivory gull is specialized for feeding on fish and invertebrates found in the surface waters at the edge of the pack ice.

Pacific Coast Migratory Bird Field Station established.—From 1850 to the present, over two-thirds of the coastal wetlands of California have been lost to man-caused activities, and four-fifths of the tidal marshes on San Francisco Bay have been destroyed by filling. Wetland losses have been less extensive along the Washington and Oregon seaboard but are still serious near cities and harbors. Because of the high values of Pacific coastal wetlands to migratory birds and the lack of knowledge of the ecology of these areas and how it is affected by man's activities, a new Migratory Bird Research Field Station of the Northern Prairie Center was established in 1973 on the campus of Humboldt State University, Arcata, Calif. Initial investigations include preparation of a bibliography on the wildlife of Pacific coast wetlands, review of marsh classification systems, and field studies of the use wildlife makes of the various types of wetlands and how these crucial wildlife habitats can be maintained or restored through various types of management.

Avian botulism losses.—There has been a steady decline in avian mortality from botulism in the United States and Canada since 1970, when 140,000 deaths were reported. As of December 1973, about 20,000 birds are known to have died from the disease. Although reporting has not been completed, records have been submitted from most of the areas in which serious epizootics have occurred in the past. Most of the documented losses (about 14,000) occurred on the Horicon National Wildlife Refuge in Wisconsin.

The immunogenicity of Clostridium botulinum type C toxin administered to mallard ducks by the enteral and parenteral routes.—Acquired immunity of some bird populations has been suggested as a partial explanation for the fluctuations in mortality from botulism in many epizootic areas from year to year. There is little evidence in the published literature, however,

that ducks acquire immunity by consuming either single intoxicating doses or repeated doses of toxin too small to induce clinical signs. A study was designed to compare the immunogenicity of several small doses of *Cl. botulinum* type C toxin administered by stomach tube with that of the same number of parenteral doses in the mallard duck.

In each of two experiments, a total of 16 doses of 400 mouse intraperitoneal LD₅₀ (the amount that kills 50% of the animals treated) of type C toxin were given to one group of 8 adult mallards by the oral route and to a second group by the intramuscular (IM) route over a period of 2 months. Two similar groups received 16 doses of dilute sterile culture medium by the same routes. Five days after the last doses were administered, each bird in all groups was challenged by the oral route with about 1 mallard LD₅₀ of toxin.

A comparison of the mortality rates shows that, although the toxin was immunogenic by the IM route, birds given toxin by the oral route had no better chance for surviving the challenge dose than did the control groups.

Perosis in a sandhill crane.—A young sandhill crane, one of six captured in Idaho and transferred to the Fish Springs National Wildlife Refuge, was submitted to the Bear River Research Station for diagnosis in August.

The chick was the smallest of the six and at the bottom of the peck order. A limp in its left leg was observed 25 days after hatching, and, within the next week, the leg became twisted so that the toes turned out at an angle of about 90°. Shortly thereafter, control of both legs and the ability to walk were lost.

Postmortem examination disclosed no evidence of infection, and a diagnosis of perosis was reached on the basis of the leg deformities.

This case is of particular interest, because a severe outbreak of perosis in young Canada geese occurred on the Fish Springs Refuge in 1964. (See Wildlife Research: Problems, Programs, Progress, 1964.) The condition is caused by deficiencies of certain vitamins or minerals or both. The particular deficiencies responsible for the young crane's deformity could not be ascertained.

Severe helminth infection in mallard ducks.—Several aspects of helminth disease were illustrated by two mallards examined at the Bear

River Research Station in 1973. The birds exhibited an extreme lack of resistance to helminth infection, both carrying thousands of internal worms, one with the largest variety of helminths (at least 25 species) yet recorded in a single waterfowl.

Necropsy findings included severe hemorrhagic and necrotic lesions and granulomas resulting from nematode infections. Helminths had invaded organs and tissues far beyond their normal habitat, and those for which ducks are abnormal hosts were present in unprecedented numbers.



A leech, attached to the inner corner of the eye and covered by the nictitating membrane, temporarily blinds this young lesser scaup. (Photo by James C. Bartonek)

These birds add to the evidence that mallards may be more susceptible to helminth infection than are other waterfowl. The Bear River collections now include 13 birds with more than 20 species of helminths, and 9 of these were mallards. There is no clear-cut explanation for such overwhelming infections, but they appear to be most commonly associated with a certain type of habitat. Most of the marshes from which the 13 birds came were deep, permanent, spring-fed marshes in mountain valleys; they were very productive of a great variety of invertebrates. Snails and amphipod crustacea (gammarids or "scuds"), which serve as intermediate hosts for a number of helminths, were particularly abundant.

Leech infestations among waterfowl near Yellowknife, Northwest Territories.—Fourteen species of aquatic birds, including 11 species of ducks, were found by Service biologists to be infested with leeches, *Theromyzon rude* and *Placobdella ornata*, near Yellowknife, Northwest Territories. Leeches infested 88% of 41 American Widgeon and 31% of 86 Lesser Scaup examined after death. Lesser Scaup captured by drive-trapping contained significantly more leeches than undisturbed ducks. Leeches attached themselves to the hose within the mucosa of the nasal chamber, at the conjunctiva of the eye, and on the skin of the body. Only two deaths of ducklings were attributed directly to leech infestations.

Patuxent Wildlife Research Center

Epizootiology of Leucocytozoon at Seney National Wildlife Refuge.—Investigation of the cause of mortality of goslings at Seney National Wildlife Refuge in the 1960's led to an ecological study of vectors and host that uncovered 107 species of black fly in an area where only four were known to exist. The story of their

ecological niches and emergence times in relation to *Leucocytozoon* transmission to goslings led first to the discovery that the species previously believed to be the vector (*Simulium rugglesi*) did not emerge until the epizootic was past, and then to implication of the actual primary vector, *Simulium innocens*. Elucidation of the life cycle of the parasite became possible only after development of methods for successfully rearing black flies in captivity, an accomplishment that proved also to be of considerable importance to persons interested in black flies as vectors of human disease in other countries.

Until 1973, insufficient breeding sites of *S. innocens* had been located to explain the abundance of the black fly, whose adults had been taken from exposed waterfowl at 71 different sites on and surrounding Seney National Wildlife Refuge. The discovery of these sites in 1973 brought the investigations full circle.

Many findings have been published during the course of this work, and highlight reports of more recent discoveries are being readied for early publication. Preparation of a full monographic report also is well under way.

MAMMALS AND NONMIGRATORY BIRDS

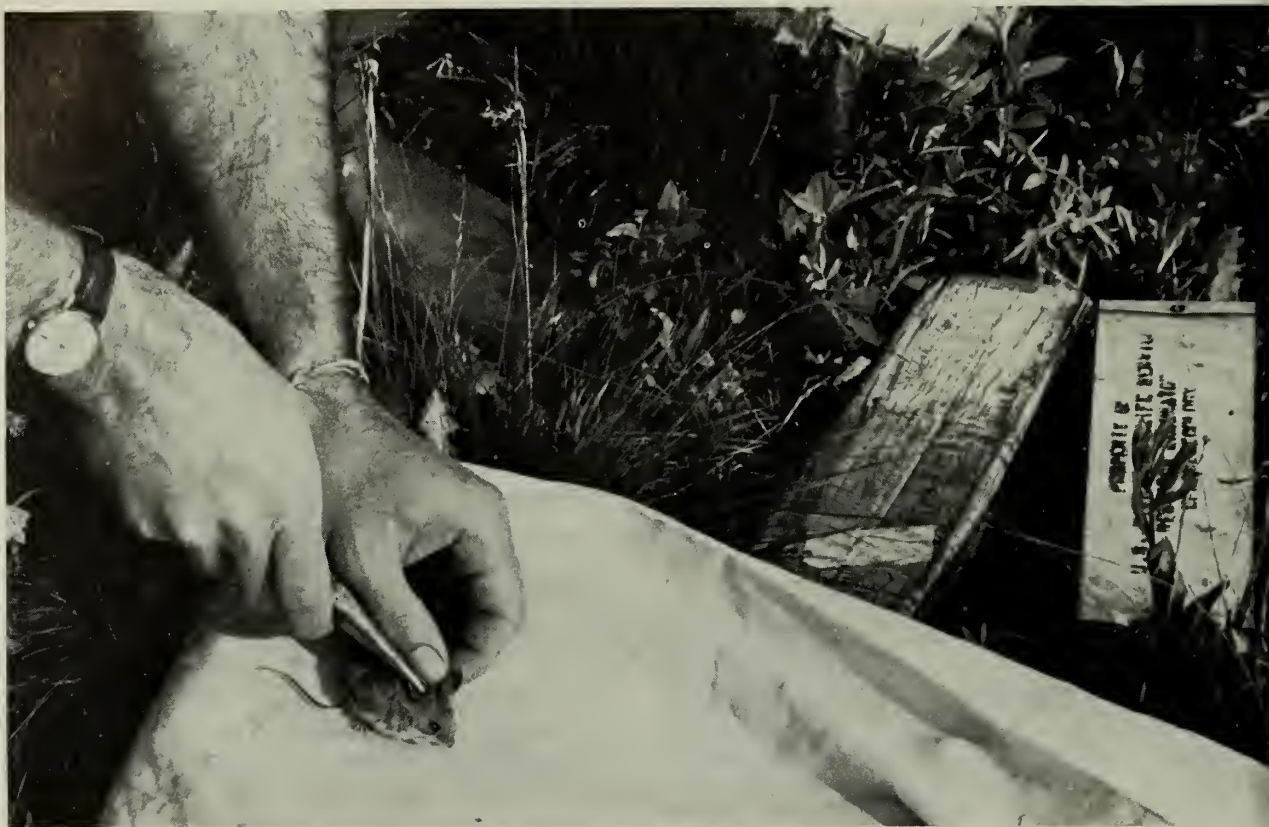
Denver Wildlife Research Center

Colonial-nesting wading birds.—Knowledge of the distribution and abundance of breeding herons and egrets is important because of the effects of land-use changes and pesticides on concentrations of these birds and because of high public interest in them. An incomplete survey of nesting sites of colonial-nesting wading birds in Texas has revealed the location, species present, and sizes of 125 sites. One hundred and eight of these were located in the forested eastern section of the State and 17 in the western section. All the western rookeries, except one that contained cattle egrets, consisted only of great blue herons. A total of 16 species of herons and egrets occupied the nesting sites in Texas. Colony size ranged from 12 to about 50,000 or more.

The rapid buildup of cattle egret populations in Texas has not pushed the species west of the 100° meridian. On its nesting ground, the cattle egret is largely a pastoral insect-eating bird

and is much favored by cattle raisers in Texas. Bird watchers, especially members of the Audubon clubs, enjoy observing wading bird rookeries because of the great concentrations and different species of birds present.

Small-mammal populations in relation to grazing treatments.—In a cooperative study with the Bureau of Land Management, Geological Survey, and Bureau of Reclamation, animal populations were investigated on grazed and ungrazed watersheds in the salt-desert shrub type (5000-foot elevation), Badger Wash Experimental Area, western Colorado. A large portion of sediment received by the Colorado River comes from this type of rangeland, and the study was initiated to determine if protection of range vegetation from winter grazing by sheep would increase plant cover, decrease runoff and sediment yields, and increase the abundance of herbivorous mammals enough to negate any improvement of watershed conditions.



Populations of the ubiquitous deer mouse are sampled on high-altitude livestock ranges by the live-trap, mark, release, and retrap method. (Photo by Vincent H. Reid)

Sheep grazed two watersheds in winter, 1967–73, at an intensity of about 5 acres per animal unit month. Their companion watersheds were protected from grazing beginning in 1953. Nine species of rodents (deer, pinyon, western harvest, grasshopper, and pocket mice, Ord's kangaroo rats, desert wood rats, white-tailed ground squirrels, and white-tailed prairie dogs), two species of lagomorphs (desert cottontail and black-tailed jackrabbit), and a very small herd of pronghorns inhabited the watersheds.

Deer mice were the only rodents caught in sufficient numbers to make a meaningful comparison between grazing treatments; other rodent populations appeared to number less than one animal per acre. Although populations of deer mice varied from about four per acre in 1968 to one per acre in mid-May 1973, no difference in population levels between grazing treatments was detected. The two lagomorph species usually numbered less than five per 100

acres and showed little preference between grazed and ungrazed range.

No appreciable change in ground cover or plant-density indices between grazed and ungrazed watersheds occurred during the period of sampling. Hence, there was no major change in habitat between grazing treatments to stimulate a different response in animal abundance.

Brewer's sparrow nesting reduced by sagebrush spraying.—Over the last three decades, many thousands of acres of sagebrush have been converted to pasture and farmlands, principally by herbicide sprays, and the effect of this extensive habitat modification on the native fauna is a matter of concern.

A brief study was conducted in south-central Wyoming to determine how spraying sagebrush with 2,4-D affects the nesting by Brewer's sparrows, a species that depends on the sagebrush habitat. Three sagebrush plants, each containing a Brewer's sparrow nest with eggs, were sprayed with 2,4-D, and nest success was

compared with that of three unsprayed nests. Although the sprayed sagebrush leaves soon discolored and became brittle, they stayed on the branches, providing shade and protection to the nests until after the young had fledged. Average nest temperature at both the sprayed and unsprayed nests exceeded ambient temperatures by 5° C or more, but differed only slightly from each other. There was also no difference between the two treatments in hatchability, growth rates, or survival of young.

Although 2,4-D spraying had no apparent effects on nests containing eggs, surveys showed that spraying had marked effects on Brewer's sparrows use of sagebrush range after the plants had lost their leaves. A 1971 census of 80 acres of sagebrush, aerially sprayed the year before, revealed 67% fewer Brewer's sparrows per acre than on an adjacent unsprayed sagebrush area. A 1972 census of the same areas showed 99% fewer Brewer's sparrows on the sprayed than on the unsprayed stand. During both censuses, the few Brewer's sparrows seen on the sprayed stand were near small areas of live sagebrush that had survived the treatment; no nests were found. Casual observations in 1973 and 1974 indicated that Brewer's sparrows had not reoccupied the sprayed area, although their numbers remained nearly constant in the adjacent unsprayed stands.

Golden eagle population survey expanded.—A study started in 1964 to monitor changes in the winter population status of golden eagles in the Southwest has been expanded to include all important wintering areas throughout the western States. During the 1973–74 wintering period, eagle populations were sampled by aerial coverage of randomly placed transects sampling 91,800 square miles in 11 western States, as follows: Colorado (NW) 4,100, (NE) 3,000, (SE) 10,000; Idaho (SW) 7,000; Montana (E–C) 12,500; New Mexico (E–C) 10,000; Nevada (NE) 7,000; North Dakota (SW) 7,200; Oregon (S–C) 9,100; South Dakota (NW) 4,600; Texas (SW) 6,000; Utah (W–C) 5,300; and Wyoming (E–C) 6,000.

Results of the 1973–74 survey indicated a projected total of 8,018 golden eagles in the sample areas. Ranked in descending order, the largest populations (in birds per 100 square miles) were 27.4 in Wyoming, 21.3 in north-west Colorado, 13.5 in Utah, and 12.5 in Mon-



Populations of the golden eagle are being inventoried annually in important wintering areas throughout the western States. An increase in the population in New Mexico during January 1974 may have indicated a general southward shift in response to an extremely low rabbit population to the north. (Photo by Karl Maslowski)

tana. The smallest populations were 1.1 in Oregon and 1.6 in North Dakota. In New Mexico a population increase from 6.7 recorded in January 1973 to 9.1 recorded in January 1974 indicates a general southward population shift, possibly influenced by the extremely low rabbit populations then present in the intermountain States.

A golden eagle nesting study also started in 1964 is continuing. Approximately 500 nesting sites in the western States are being monitored each year to determine overall nesting activity and productivity. Compared with the previous 9-year average, both nesting activity and productivity declined 35 to 40% during the 1973 and 1974 nesting seasons. Again, the low population level of jackrabbits and cottontails, mainstay of the golden eagle's diet, is believed responsible for the decline.



Elk wintering at the National Elk Refuge, Jackson Hole, Wyo. (top), can be fed better and more efficiently with alfalfa pellets than with baled hay. After this was established experimentally (bottom), a "pellet wagon" was developed that would distribute 10 tons of pellets to 2,500 elk in 40 minutes. (Photo by Russell L. Robbins)

Better means for winter feeding of Jackson Hole elk.—The management objective of the Fish and Wildlife Service at the National Elk Refuge, Jackson Hole, Wyo., continues to be improvement of the habitat for the wintering population of free-ranging elk. However, winter elk populations in excess of the range's carrying capacity, poor distribution of the elk, and weather conditions make supplemental feeding necessary during most winters. For the past 35 years, this has meant distribution of baled hay in several feeding areas.

In 1970, faced with the loss of local hay sources, biologists began investigating the possibility of substituting alfalfa pellets. These are made from sun-cured alfalfa hay (no additives) and have a number of advantages over baled hay. Pellets contain the alfalfa leaves as well as the stems. The quality is high and uniform, and can be controlled. Pellets can be handled easily by mechanical conveyors; conceivably, one man with the proper equipment could feed all the elk on the Refuge, whereas six men would be needed to distribute baled hay. Finally, pellets can be widely scattered so that the wintering herds can be broken into small groups and the feeding areas moved frequently, thereby reducing the disease hazard that is always present when large groups of animals are forced to remain in confined areas over long periods.

Four years of study have shown that elk on the Refuge readily accept the alfalfa pellets. Penned elk on a daily ration of 8 pounds of pellets per elk gained more weight than elk on a daily ration of 10 pounds of baled hay; the difference was not significant for adults but was for calves. There was a 4% waste of alfalfa pellets (almost exclusively dust) and a 24% waste of baled hay.

Later tests confirmed that pellets could be distributed with much less labor than baled hay. Over a 55-day feeding period, in winter, it took one man, using a 10-ton wagon pulled by a TD-20 bulldozer, only 5 hours a day to feed pellets at the 8-pound rate to herds totalling 5,000 elk.

Moose habitat research on the Kenai Peninsula.—As part of a cooperative moose research project with the Alaska Department of Fish and Game, the Fish and Wildlife Service is conducting research on the quantity and quality of moose forage on the Kenai National



Population dynamics and physiological parameters are studied on captive moose at the Kenai Moose Research Center, Alaska (top). Analysis of rumen liquor, removed from tranquilized moose, provides information on nutrition (bottom). (Photos by John L. Oldemeyer)

Moose Range. These studies are carried out in four 1-square-mile enclosures in a 25-year-old burn.

Detailed surveys in these enclosures have indicated that paper birch saplings make up over 80% of the available winter forage, while willow, aspen, and alder make up much of the remainder. Lowbush cranberry is an abundant low-growing shrub that is second to birch in importance in the moose's diet, but it is not readily available under deep snow.



The pinyon-juniper plant association. In Utah, and elsewhere in the west, large amounts of this association are being eliminated to produce better grazing land. (Photo by Maurice F. Baker)

Nutrition studies (in vitro digestion trials and analyses of nutrients and minerals) have shown that the current growth of the taller-growing shrubs and saplings is of the most nutritional benefit to the moose. Birch produces from 70 to 80 pounds of new growth per acre each year, while aspen, willow, and alder together produce only a tenth of that amount. Lowbush cranberry, on the other hand, has a similar nutritional quality throughout the plant and produces a total above-ground weight of several hundred pounds per acre. Unfortunately for the moose, paper birch, the only abundant browse species available throughout the year, has the poorest nutritional quality of the five major forage species.

Response of rodents and small birds to clearing and seeding pinyon-juniper range.—A pinyon-juniper area on the Benmore Experimental Range in Utah was studied before and after treatment to ascertain the effect of clearing on small bird and rodent populations. The trees were cleared by chaining and were windrowed in 1972; part of the windrows were burned in 1972–73. Although the number of species of birds present did not change in the first year, total numbers declined markedly after treatment. Brewer's sparrows, chipping sparrows, mountain bluebirds, plain titmice, and scrub jays decreased after treatment, but lark sparrows increased. In 1974, concurrent with the second year's growth of seeded grasses

and legumes, both numbers and kinds of birds were similar to pretreatment. Several species appeared to be held in the area by scattered clusters of trees left undisturbed by the treatment. No differences in kinds or numbers of birds were detected on control areas.

Only one deer mouse was caught immediately after the windrows were burned in 1973, but by fall, a small population was established. Pocket mice, which were decimated by mechanical removal of trees in 1972, reappeared in low numbers in late summer 1973. In spring and summer 1974, when seeded grasses and legumes were in their 2nd year of growth, trapping revealed a substantial increase in both species.

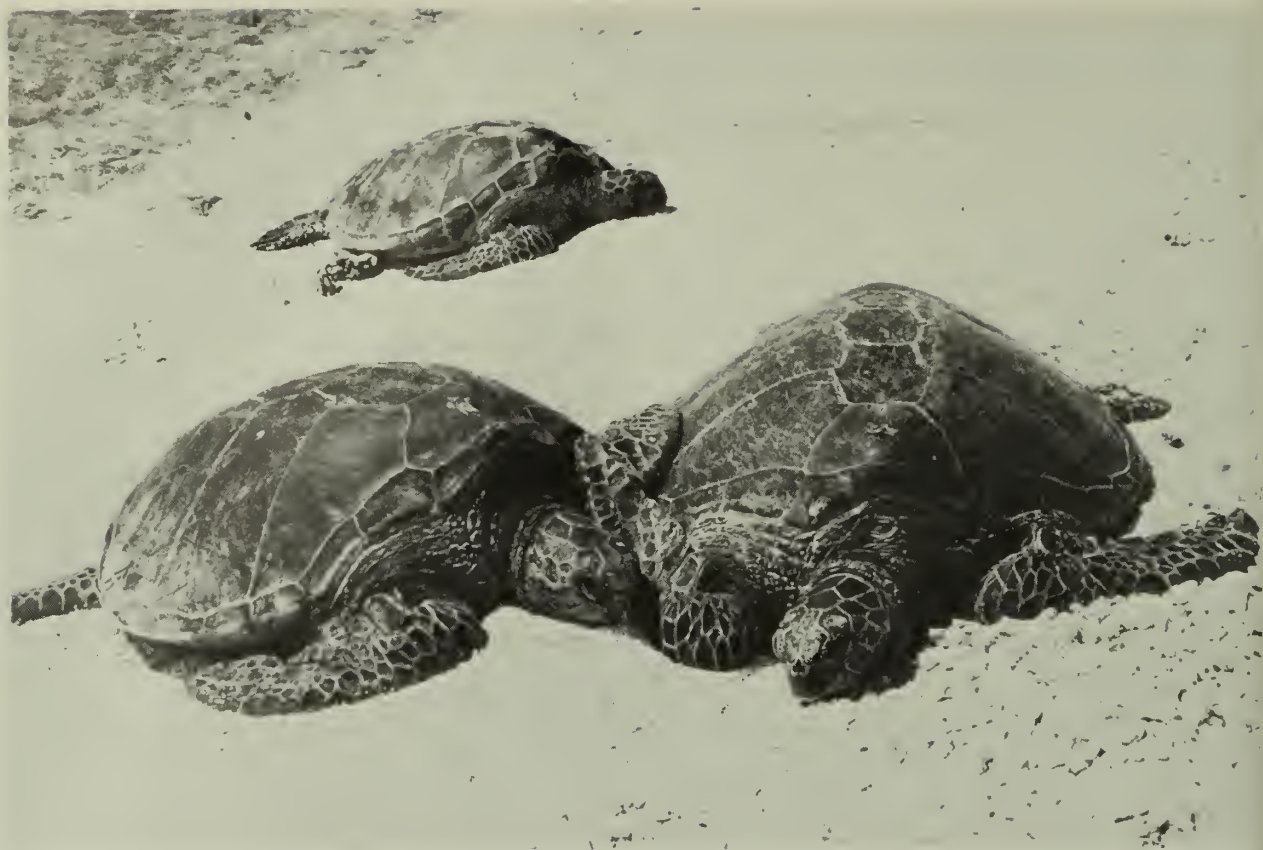
National Fish and Wildlife Laboratory

Marine mammals.—In accordance with a requirement of the Marine Mammal Protection Act of 1972 (Sec. 103), some status reports on marine mammals were submitted to Congress and published in the Federal Register. Reports providing information on past and current distribution, habitats, and general biology were prepared for the polar bear, sea otter, Pacific and Atlantic walruses, dugong, and West Indian, Amazonian, and African manatees. Information was provided to the Secretary of Interior and the Department of State with regard to the Conference to Prepare an Agreement on the Conservation of Polar Bears, and there was participation in the Conference. There was considerable input into Service, Department, and Department of State activities in connection with the Agreement of Cooperation in the Field of Environmental Protection with the USSR, and commitments have been made to conduct cooperative studies on the polar bear and Pacific walrus with scientists of the USSR. We also participated in the Workshop on Manatee Research sponsored by the government of Guyana and the National Academy of Sciences.

Non-marine mammals.—An estimate of daily infant mortality for the bat colony at Carlsbad Caverns was determined. Study of specimens of various species of *Molossus* (free-tailed bats) in the National Museum collections suggested palatal ridges as a promising systematic character for determining relationship in this taxonomically confused genus. A review of reproduction in New World bats was compiled.

The status of Merriam's pocket mouse and the relationships between it and similar taxa were determined, providing information on identification of species and populations. A detailed review of the systematics of the genus *Didephis* (opossum) was completed. A restricted population of the eastern chipmunk was located in west Florida, which is the southernmost limit of the geographic distribution of this form. Some relationships with other vertebrates and habitat requirements were determined for two threatened species of kangaroo rats. Tabulations of mammals imported into the United States in recent years have been completed. The status of primates in Costa Rica was determined and policies were developed with regard to their threatened and endangered categorization. A feasibility study for a project on the biology of the Marianas fruit bat on Guam revealed that the Guam fruit bat population is endangered and threatened with extinction in the near future. The two major factors relating to the decrease in populations are habitat destruction and poaching.

For the Division of Law Enforcement, information and services provided included reviews of applications for permits to import endangered species and wildlife from Central and South America, the identification of wildlife from Central and South America, and the identification of more than 12,000 mammals or parts thereof. Information on the status of primates was provided to the I.U.C.N. (International Union for the Conservation of Nature and Natural Resources) Survival Service Commission. Specimens of sciurids were identified for the Division of Refuges. Information was given to the New Mexico Department of Game and Fish for use in review of applications for permits to take mammals in the State. Some information was provided to the States of Maryland, Louisiana, and Florida with regard to the distribution and taxonomy of rodents and rabbits and to the National Park Service with regard to management of bat populations on public lands and the distribution and ecology of mammals of Alaska. Data on distribution, ecology, and systematics of rodents were provided to the Department of Agriculture. Information on cytogenic and karyological techniques and methods for analyses of census data were presented to the National Science Foundation,



Green turtles. Although endangered on the Atlantic Coast of the United States, the species is still common in the Hawaiian Islands. These were on Pearl and Hermes Reef. (Photo by Van T. Harris)

National Academy of Sciences, and the International Biological Program. Data on methods of data storage and retrieval and the application to systematics were provided to the American Society of Mammalogists. Information was provided to the scientific community by publication of interim results and by presentation of reports at scientific meetings, as well as through response to specific requests from researchers.

Reptiles and amphibians.—Field surveys of marine turtle nesting were conducted along the Atlantic Ocean. Analysis of annual nest counts for specific beaches suggests a general decline in numbers of nesting loggerhead turtles, although a few instances of increased nesting were observed. Almost all suitable beaches are surrounded by areas of development or severe erosion. Predation on the eggs and hatchlings was found to be a serious problem to the species. The green turtle, a commercially valuable

species, suffers from loss of the nesting habitat and poaching of nesting females and eggs. Its status as an endangered species is considered to be appropriate. The occurrence of leatherback turtles is both rare and random in the United States. No evidence has been found to indicate that the species has ever been common, and current population trends are difficult to evaluate. A Kemp's ridley turtle was found nesting on Padre Island, Texas, on 13 May 1974. This turtle is believed to be one of 79 released in 1966 as part of a restocking program and may indicate the first successful restocking of a depleted nesting beach.

The effects of two environmentally disruptive activities in the Mojave Desert were ascertained using the numbers and biomass of lizards. Sheep grazing reduces ground cover necessary for some lizard species. The use of off-road vehicles on the desert also eliminates vegetation and adversely affects lizard populations.

Population density, distribution, and ecology of the desert tortoise were studied. Literature surveys and examination of specimens were conducted in connection with a study of exotic herpetofauna that have become established in the State of California. A survey of the status of North American amphibians was completed and studies on the ecology of the Pacific pond turtle were continued.

Appendices on reptiles and amphibians were drafted for the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the new Endangered Species

Act, and applications for permits to import reptiles and amphibians were reviewed. Seven specimens or parts thereof were identified for the Division of Law Enforcement. Information on distribution of amphibians was provided to the Department of Agriculture. Data on venomous snakes were given to the National Park Service and to the State of Maryland. Lizards from the South Pacific were identified for the Air Force, and photographs of sea turtles were identified for the National Wildlife Federation. Information was furnished to the scientific community in reply to requests.

RESERVOIRS AND RELATED WATERS

Fish Control Laboratory

Use of antimycin in fish control.—Antimycin (Fintrol) is generally applied as a single application to lakes or for 6 to 12 hours in streams. The piscicide loses its toxicity quickly in water and poses little hazard several days after treatment. Invertebrates, such as backswimmers, crayfish, and clams, are much more resistant to antimycin than are fish. The data collected to date indicate that if recommended use patterns are followed, antimycin should have no significant effect on invertebrate populations in treated waters.

A long-term field trial to eliminate an undesirable carp population by applying antimycin (Fintrol-5) at 12 ppb in a 2-acre pond at the Max McGraw Wildlife Foundation, Dundee, Ill., was begun on 17 October 1972. Two conspicuous developments were noticed after the treatment: Turbidity decreased within 1 week to the extent that the bottom was visible at a depth of 10 feet; and dissolved oxygen was depressed by 10 to 12% on the day of and for 1 day after treatment (2 days after treatment it returned to pre-treatment levels). Submerged aquatic plants have flourished.

Rainbow trout were stocked in the pond 1 week after treatment. The trout gained an average of 3.1 inches in length and 3.9 ounces in weight in the first 7 months. After 1 year, a rainbow trout was caught which measured 15.4 inches and weighed 1.7 pounds.

Antimycin was tested as a companion tool and possible substitute for Bayer 73 lampricide in sea lamprey control. Since lamprey larvae

burrow into the bottom of streams and lakes, any applied lampricide must reach this stratum. A new formulation of antimycin has been developed which has a coating on the granules to permit them to sink about 30 feet before the toxicant is released. In the tests, sea lamprey larvae were caged on the bottom and fish were caged at selected distances above the bottom.

In each trial about 90% of the caged lamprey larvae were killed. In one trial, most of the fish 5 feet or more above the bottom survived. In the second trial, caged fish at all depths were killed, indicating extensive upwelling from the bottom. No wild game fishes were killed in either trial.

It has been suspected that sunlight reduces the effectiveness of antimycin applications. Solutions of antimycin maintained at various temperatures, hardnesses, and pH's and exposed to an ultraviolet light source for 2 hours showed marked reductions in activity. Use of acetone as a solvent increased the loss of activity. Loss of antimycin activity due to light penetration was observed 12 inches below the surface (Secchi disc reading 79 inches) but not at 24 inches. Under normal field conditions, the loss of activity due to photodegradation should not affect the success of applications.

Many waters to be treated to eliminate undesired fish populations contain heavy growths of aquatic plants. Sprigs of *Elodea densa* were placed in water containing ¹⁴C-antimycin, removed at 0, 1, 3, 6, and 24 hours, then frozen. Sprigs also were removed at 24 hours and placed in antimycin-free water for desorption

studies. Results indicate that *Elodea densa* apparently absorbs and degrades antimycin and suggest that other aquatic plants may do likewise.

Comparative toxicity of rotenone.—Various rotenone formulations were compared for their activity against aquatic organisms. Pro-Noxfish (2.5%) was significantly more toxic to rainbow trout than either Noxfish (5%) or rotenone powder (33%) when concentrations were based on the level of active rotenone.

Under laboratory conditions, the toxicity of Noxfish to black bullheads was not affected by pH 8.5 or greater but was increased at pH 6.5. Turbellarians, mollusks, crustaceans, and insects were less susceptible to Noxfish than fish. Ostracods proved most susceptible, and snails were most resistant.

In plastic pools, the activity of rotenone (Noxfish) on adult carp and black bullheads was reduced by both a moderately heavy plankton bloom and low temperature. In warm water (24–28° C), both species were eliminated faster and by lower concentrations than in cold water (14.5–18° C).

National Reservoir Research Program

One-fourth of all U.S. freshwater sport fishing now occurs on 1,500 large reservoirs (greater than 500 acres) encompassing about 10 million acres at average pool levels. These manmade lakes have thus greatly altered angling habits and increased water-based recreation in many parts of the nation. Angling pressure on reservoirs has doubled since 1960, and is expected to redouble in the next quarter-century. Estimated angler-days on reservoirs (132 million) exceeded total saltwater angler days (114 million) in 1970.

Reservoirs vary greatly in their capacity to produce fish, presenting living conditions ranging from those of a sluggish river to those of a natural lake. Most have higher rates of water exchange than natural lakes, as well as greater shoreline lengths in proportion to surface area. Reservoirs age faster, as most lie in more fertile watersheds, and the changes in fish population structure are also more rapid and complex. Water level fluctuations are usually greater.

Outlets in most dams are placed at various depths rather than at the surface as in natural lakes. Density currents alter stratification when

turbid flood waters flow toward the outlet. Pumpback storage reservoirs create sudden current flows, and quick changes in water level and water quality. Heated waters are entering reservoirs from an increasing number of powerplants. All of these anomalies pose management problems requiring long-term research effort for solution.

Nearly every fish management method used on natural lakes has been attempted on large impoundments. Stocking, provision for spawning sanctuaries, special rearing ponds, introduction or eradication of aquatic vegetation, rough fish removal, shad control, and other techniques have not produced desired results in most instances. New and improved management methods must be found if the anticipated angling demand is to be met.

The Fish and Wildlife Service has been engaged in reservoir research since 1962, with study emphasis on the huge mainstem Missouri River impoundments in South Dakota, the White River reservoirs in Arkansas and Missouri, and on a nationwide analysis of fish production and harvest based on data available from other agencies. In 1972 we began a study of heated water and pumped storage effects on the fishery resources of Duke Power Company's Keowee and Jocassee reservoirs, S. C. In 1974 research was started on the effects of releasing water from varying outlet depths on the fishery resources in DeGray Reservoir, Ark., and contiguous streams.

Nationwide analysis of reservoir fish production and angler harvest.—The continuing effort to accumulate published and unpublished data from fishery agencies has now produced fish standing crop information from 185 reservoirs (predominantly southern), including nearly 2,000 individual samples from coves. Angler use and sport fish harvest data have been obtained on 150 reservoirs.

Partial correlation analyses of the expanded standing crop data base were completed, involving the influence of 11 environmental variables on fish crops in reservoirs of four water quality and use types. New and revised multiple regression formulas have been derived to predict total fish crop; total crop less clupeids; clupeid crop; sport fish crop; total black bass crop; and largemouth, spotted, and smallmouth bass crops. A revised compilation of 31 standing



Potential areas of optimum production of sport fishes (salmonids, pike and pickerel, serranids, black basses, crappies, and sauger or walleye) in U.S. waters, based on selected water quality criteria dealing with pH, ionic concentrations, and turbidity. Areas meeting all three criteria are indicated in black; areas meeting two of three criteria are indicated in gray.

crop estimation formulas and 14 angler harvest and use estimation formulas is available on request (11 pages, mimeo).

The environmental variable appearing most importantly in standing crop formulas was total dissolved solids, followed in frequency by mean depth, outlet depth, growing season length, water level fluctuation, relative shoreline length, age of impoundment, storage ratio, reservoir area, and maximum depth. The correlation and regression analyses indicate that highest crops of reservoir sport fishes occur in (1) moderately hard waters (100–350 ppm total dissolved solids) where (2) ionic concentrations of carbonate-bicarbonate exceed those of sulfate-chloride. Studies have also shown that (3) low turbidity enhances sport fish crops.

Using overlays of hydrologic maps depicting these three important criteria, we prepared a map of the nation (see accompanying figure)

to identify potential areas of best sport fish production. The darkest-shaded regions meet all three criteria, identifying probable areas of optimum production. Lightly-shaded areas indicate above average potential and unshaded areas, below average potential. There are numerous exceptions to this categorization, resulting from localized conditions and man-induced changes; but the precept should be of value to fishery agencies in preparing management plans on a regional basis.

Geographical areas meeting all three water quality criteria (darkest-shading) are positively related to nonresident fishing license sales—a reasonable indicator of angling quality. The leading 12 States in nonresident freshwater fishermen in fiscal year 1973 were Wisconsin, Minnesota, Tennessee, Michigan, Arkansas, Colorado, Florida, Missouri, Oregon, Montana, Idaho, and Wyoming.

Evaluation of predator stocking.—Questions concerning the advisability of stocking large predator species into existing reservoir fish populations prompted member agencies of the Reservoir Committee, Southern Division, American Fisheries Society, to launch a coordinated 2-year study of 26 reservoirs in 11 States where periodic stocking of striped bass, walleye, rainbow trout, or combinations of these species is in progress. By simultaneous study of selected environmental variables, fish standing crop, and angler harvest, the Committee hopes to identify factors that influence success or failure of the introduced predators, to determine harvest rates of the predators, and to gain new insight into predator-prey relationships.

The National Reservoir Research Program is charged with collation of the field data collected by cooperating agencies, its preparation for computer processing, and for correlation, regression, and other statistical analyses necessary for quantitative evaluation. About 60% of the anticipated information has been received.

Preimpoundment predictions of fish crop and angler harvest.—Reports describing expected fish standing crops, relative abundance, angler use and harvest, and commercial fish harvest have been completed on over 100 reservoirs (planned, under construction, or existing) for use of the Division of River Basin Studies and other agencies. Predictions have been furnished concerning a number of reservoir projects involved in litigation or Environment Impact Statement reviews, including: Gillham (Ark.), Rodman (Fla.), Tock's Island (N.J.), Harry S Truman (Mo.), Trotter's Shoal (Ga.), Davis Project (W. Va.), Bell Foley (Ark.), and Sprewell Bluff (Ga.).

Multiple-outlet reservoir study.—This project was initiated in 1974 to study the effects of releasing water from various depths on the aquatic resources of DeGray Reservoir and its contiguous streams. A partly staffed and equipped field study team is housed on the Ouachita Baptist University campus in Arkadelphia, Ark. Research emphasis is directed toward comparing the effects of hydropower releases from the epilimnion and the hypolimnion on water quality, plankton production and distribution, and production and yield of the principal fishes.

Findings will be compared with predictions obtained from elaborate physical and mathematical models of DeGray Reservoir and its watershed by the Corps of Engineers, Vicksburg Waterways Experiment Station. Results are to be used in designing and operating future multiple-outlet reservoirs and redesigning outlets of existing ones.

North Central Reservoir Investigations

Effects of water management on fish populations.—The fish populations of four Missouri River reservoirs—Lake Oahe, Lake Sharpe, Lake Francis Case, and Lewis and Clark Lake—have been measured since 1965 to evaluate the ecological changes during the filling stage and early years of normal operation, and to determine the effects of various water level schedules and water exchange rates on fish. Information is collected on fish abundance, growth, mortality, and reproduction, by seines, trawls, traps, and gill nets. The water management programs developed by the U.S. Army Corps of Engineers are designed principally for power generation, flood control, and navigation, but modifications have been made to benefit fish, wildlife, and recreation functions.

During 1973, inflow into the reservoir system was slightly below normal and the water management programs had the following features: (1) lower water exchange rates on all reservoirs; and (2) low water levels on the storage reservoirs. The fish populations in each of the four reservoirs reacted differently to the water management programs.

Lake Oahe is a large (500 square miles) storage reservoir which reached normal operating level in 1967. In 1973 conditions for fish spawning were poor because of low spring water levels, poor growth of terrestrial vegetation on exposed bottoms in 1972, and low flows in tributary streams. Most fish reproduction takes place during the spring within the shore zone of embayments or in the tributary streams; essentially no fish reproduction takes place in the open water areas of the main reservoir. The catches of young-of-the-year fish during June–September 1973 were 72% below the 1968–73 average, and 12% below those in 1972. The survival rate of these fish from the spring spawning season to September was higher than normal, however, and the 1973 year class was

about average for some fish species. Assessments in October indicated that goldeye, freshwater drum, white bass, and walleye had average year classes although overall fish reproductive success was low. The adult fish catch declined 4.4% from 1972 to 1973, as compared with a drop of 7.7% from 1971 to 1972. From 1968 to 1973 northern pike, white crappie, black crappie, and yellow perch have declined more than 75% and walleyes, white bass, saugers about 30 to 40%; channel catfish have increased more than 100%.

Lake Francis Case is a smaller (148 square miles) storage reservoir in which low inflows caused fishery responses similar to those in Lake Oahe. Information back to 1954, the initial year of impoundment, has shown that fish abundance appears to be related to spawning success, and that the best fish reproduction has occurred when water levels rise during May–June over shoreline vegetation. Fish reproduction in 1973 was the lowest ever recorded and was associated with adverse water levels and little or no shoreline vegetation. The 1973 adult fish catches declined 37% from 1970, the last year of sampling. Walleye and goldeye were again the most common fish species sampled, although channel catfish were common.

In contrast to lakes Oahe and Francis Case, Lake Sharpe (88 square miles) and Lewis and Clark Lake (44 square miles) had excellent fish reproduction in 1973. Both Lake Sharpe and Lewis and Clark Lake have high water exchange rates, and low water level fluctuations; during low inflow years, currents are greatly reduced in both reservoirs. In Lake Sharpe seine catches of young-of-the-year fish increased 61% over 1972, and trawl catches nearly 250%. Gizzard shad, yellow perch, black crappie, and white crappie showed the greatest increases. Emerald shiner abundance continued its downward trend. A greater abundance of zooplankton and reduced displacement of embryos and early-stage larvae by current appeared to be the key factors for increased numbers of young fish. The adult fish catch in Lake Sharpe was 10% above 1972, and only 7% below the record year of 1971. The growth rate of walleye, the most abundant species captured, increased—probably as a result of the large numbers of small fish available for forage. Other fish species that showed noticeable in-

creases in abundance were channel catfish, carp, shovelnose sturgeon, goldeye, and yellow perch. A creel census was conducted from June 1973 to June 1974 to estimate total catch by use of a combination of aircraft counts and fisherman interviews.

In Lewis and Clark Lake, overall fish reproduction was the highest recorded but much of the increase was contributed by freshwater drum. Other species showing increases were channel catfish, white bass, yellow perch, sauger, and walleye. Past studies and statistical models on this reservoir ecosystem have shown that low water exchange rates during the summer months are directly associated with high fish reproduction. Zooplankton abundance is higher than normal during years of low water exchange and few young fish are lost from the reservoir through the discharge. The high 1973 catches reinforced these findings.

Several adverse environmental conditions still limit the reproduction of such littoral spawning fish species as white crappie, gizzard shad, carp, and bigmouth buffalo in Lewis and Clark Lake. The water levels are lowered about 3 feet from March to July each year because of a flood control function of the reservoir. Large areas of desirable spawning habitat become exposed, and there are few quiet water areas. Shoreline erosion has reduced the amount of protected areas by filling in creek mouths, opening these areas to wind action and reducing overall shoreline diversity.

Effects of peaking of reservoir discharges on the biota.—Hydroelectric generating facilities are particularly suitable for generation of peak power. With energy shortages, there are indications that peaking functions of hydroelectric plants will increase and nuclear or fossil fuel plants will furnish base power loads. We have data to show the effects of annual or seasonal differences of discharge patterns on fish and environmental conditions but have little information on the effects of changes in discharge patterns within a 24-hour period. Seasonal and annual differences in discharge from Lake Oahe into Lake Sharpe influenced summer zooplankton abundance, water temperature, water clarity, and annual variations in abundance of young-of-year fish. Discharge patterns from Lewis and Clark Lake affect both the tailwater and lake fishery.

Results of this previous work prompted the design and initiation of a 3-year study in April 1974 to determine in greater detail the effects of variable water discharges within a 24-hour period on aquatic organisms. Specific objectives of this study are: (1) to estimate downstream losses of zooplankton and young fish in relation to discharge rate; (2) to estimate the mortality of zooplankton and young fish as a result of their passage through the power turbines; and (3) to determine the relative abundance and behavior of young and adult fish in the tailwaters in relation to low, moderate, and high water discharges. Knowledge from such studies is needed to evaluate hydroelectric power discharge programs and to formulate water management plans.

Long-term limnological assessment.—Since 1966 cruises have been made on Lake Sharpe from May to October each year to measure temperature, zooplankton, turbidity, conductivity, and light transmission. The 30% lower water exchange rates during 1973 had the following effects: (1) zooplankton volumes were 45% above those in 1972, and abundances were more widely distributed throughout the reservoir; (2) summer water temperatures were higher throughout the reservoir, and 1 to 3° C warmer in the outflow; (3) there was no vertical stratification; and (4) turbidities were higher than in any year since 1969. Overall, the reduced water exchange rate during the summer of 1973 afforded favorable conditions for biological production.

Automatic plankton samplers are located in the discharges of Lake Francis Case and Lewis and Clark Lake to measure zooplankton on a year-round basis. Analysis of the data from Lake Francis Case, from January 1966 to January 1973, revealed the seasonal and annual variations one might expect in a reservoir of this type. The common zooplankton taxa—*Daphnia*, *Diaptomus*, and *Cyclops*—had similar seasonal distributions each year. Curves and equations were derived to show the annual distribution of standing crop as a function of time. The major changes over the 1966–73 period were: *Cyclops* decreased fourfold to fivefold; *Daphnia* decreased twofold to fourfold; *Diaptomus* increased about twofold; and overall zooplankton abundance decreased about threefold. Annual changes in abundance could not

be explained by water management. The most probable cause for the general decrease was the reduced inflow of nutrients and zooplankton from upstream after Lake Oahe reached full pool in 1967.

Analysis of zooplankton discharged from Lewis and Clark Lake from 1964 to 1973 showed that densities could be grouped into three periods—1964–69, 1970–72, and 1973. In 1964–69 standing crops were relatively high and nearly stable; in 1970–72 overall densities decreased 64% and *Cyclops* decreased threefold; in 1973 overall density doubled from 1970–72. The major factor influencing the changes was water exchange rate; zooplankton abundance decreased as water exchange rate increased.

Factors controlling biological production.—Many water quality data are collected routinely on reservoir systems but biologists have difficulty in utilizing these data to predict or judge biological production. Simple models that would predict biological production from readily available data would have wide use; the present research was conducted to derive such a model. Five stations on the Missouri River reservoirs with great differences in biological activity were studied over a 15-month period. Fourfold to tenfold differences were found in average conditions of turbidity and phytoplankton productivity, and twofold to threefold differences were noted in concentrations of various chemical nutrients. Chlorophyll, total solar radiation, and turbidity were the three most important variables found in a multiple regression analysis of photosynthetic production. The equations derived accounted for 65 to 80% of the variation in the dependent variable, and should prove useful in estimating productivity.

Fish spawning and nursery areas.—Understanding of warmwater fish spawning and nursery ecosystems in large storage reservoirs is being sought to establish criteria for assessing effects of impoundment and water management practices on the early life stages of individual species or groups of similar fishes, and to assemble information for the possible development of artificial spawning and nursery areas. The work is being conducted in the three major tributary embayments of Lake Oahe, with special emphasis on determining the effects of sedimentation on developing eggs and fry, and

determining the adequacy of the zooplankton food supply for young fish.

Major findings indicate that most fishes spawn in the river portion of these embayments, and some species spawn near shore in the upper reservoir portion of the embayment; only yellow perch are known to spawn in the lower portion. Apparently no species spawn in the open water areas of the main reservoir. River flow, water level, and substrate are the primary factors in determining initial spawning success of most species, whereas zooplankton abundance and the abundance of the adult stock of predatory fishes seem to be two important factors governing the survival of young after hatching.

Remote sensing of reservoir environments.—This research was conducted to determine the feasibility of using remote sensing techniques to monitor turbidity, chlorophyll, and water temperature on large expanses of reservoirs. Data from the Earth Resources Technology Satellite (ERTS) collected during two overflights were combined with extensive field data. Good correlations between ground-truth data and ERTS images were found for all three characteristics when cloud cover was lacking. At present, two major drawbacks are known for the use of ERTS data as a routine monitoring method: First, images from one overpass cannot be quantitatively correlated to images from other overpasses without concurrent ground data; second, ERTS data cannot be used if the sampling area is obliterated by cloud cover. During the first 167 ERTS passes over the Missouri River in South Dakota, 33% were cloud free, 8% were partially cloudy, and 59% were completely overcast. There would seem to be a potential for remote sensing of large reservoirs. However, much more research on methodology is needed before the techniques become routinely operational.

Effects of reducing a fall drawdown on benthos.—Lake Francis Case is drawn down each fall to provide capacity for water released from upstream reservoirs during winter power generation. The depth of the drawdown was reduced from about 35 feet during the 1953–70 period to 18 feet in 1971–73. During 1953–70 about 32 square miles more reservoir bottom was exposed each fall than during 1971–73. Data collected in May of 1966, 1967, 1972, and 1973 indicated a fourfold increase in number of

benthic organisms per unit area in the shore zone after the drawdown was reduced in 1971. In September the reduced drawdown had no quantitative effects.

Terrestrial vegetation on inundated shorelines.—The success of fish reproduction in the Missouri River reservoir with fluctuating water levels is directly related to the amount of terrestrial vegetation on exposed bottoms when these bottoms are re-inundated. Dead inundated vegetation increases the production of fish foods, serves as a substrate for the deposition of fish eggs, and forms cover for protection of young fish. If the plant succession patterns on various habitat types and under various water level programs were understood, the vegetation communities which might become established with various water management programs could be predicted.

During 1971–73, vegetative growth was measured along 50 transects established in each of two fluctuating reservoirs—Lake Oahe and Lake Sakakawea. The principal developments in the study were as follows: (1) The flora of the shoreline zone was described taxonomically by community; (2) habitat characteristics such as soil texture and chemistry were described; (3) changes in water level with time were shown to be key factors in controlling plant abundance; (4) wave action and shoreline erosion were dominating influences at several stations; (5) cattle grazing reduced the vegetation in some areas; and (6) several plants were identified that showed potential for planting on exposed shoreline. As a result of this work, the U.S. Army Corps of Engineers has fenced some areas to protect critical fish spawning areas from grazing. The University of South Dakota is continuing the research and has established several plots of experimental plant communities.

South Central Reservoir Investigations

Research conducted by the South Central Reservoir Investigations was designed to describe and explain biological and physico-chemical conditions influencing fishery resources in reservoirs. Emphasis was on two White River impoundments—28,200-acre Beaver Reservoir (impounded 1964) and 45,440-acre Bull Shoals Reservoir (impounded 1951).

Effects of high water.—Heavy rainfall during the winter-spring periods of both 1973 and 1974 produced the highest water levels in the White River impoundments since studies began in 1963. High inflows resulted in reduced transparencies, increased water exchange rates, and accelerated depletion of summer hypolimnial oxygen depletion in both Beaver and Bull Shoals reservoirs.

Noteworthy variations in the seasonal pattern of zooplankton abundance were observed. Years of average inflow have been associated with a single spring peak of zooplankton abundance which peaks in late April and May, then rapidly declines to a low level throughout the remainder of the year. In 1973, the spring pulse in Bull Shoals extended into July; in Beaver Reservoir, the spring pulse was delayed by high turbidity.

Colonization of benthic organisms on newly flooded areas of Bull Shoals Reservoir was rapid, but there was a delay of at least 90 days in the buildup of large numbers of organisms. Chironomids were the most abundant group in these areas but damselfly and mayfly naiads were also numerous. Summer benthos standing crops were high in Beaver Reservoir, and composition was similar to that in previous years.

Factors influencing black bass year-class strength.—An understanding of the timing and causes of mortality among major sport and forage fishes is essential to the development of better management techniques. Studies to determine the spawning requirements and reproductive potential of largemouth, smallmouth, and spotted bass in Bull Shoals Reservoir continued during 1973 and 1974. Standardized underwater observations were conducted weekly during the 8- to 10-week spawning season in five areas which have been studied since 1967, and routinely since 1969.

Spawning by all three bass species began on or about 19 April 1973. Extremely high water levels (approximately 30 feet above conservation pool level) during the spawning season substantially increased the amount of spawning habitat in coves, and provided extensive cover for bass nesting in flooded vegetation. Largemouth and spotted bass avoided a precipitous shoreline area for spawning, as they also did in 1968 and 1969, two other years when spring



Operating electrofishing gear along the shoreline of Bull Shoals Reservoir to estimate abundance of largemouth, smallmouth, and spotted bass.

water levels were high. Smallmouth bass nests, however, were more common in this area than during any previous spawning period in the 1969–74 period. Nest densities in coves were near normal, indicating a displacement of the steep-shoreline spawners into the expanded cove habitat.

In 1974, the first bass nests were observed on 18 April. The water level began rising on 21 April, and continued throughout the spring. Largemouth and spotted bass returned to the steep shoreline area for nesting, and smallmouth bass nested in greater numbers than previously observed. Nest density in coves was relatively low, and for smallmouth bass was the lowest yet recorded during the study. Largemouth bass nest density exceeded that of spotted bass in the cove study areas for the first time since observations began in 1967.

Estimates of eggs nearing maturity in female smallmouth bass collected in April ranged from 1,550 to 21,984 (mean, 6,064).

Eggs removed from seven smallmouth bass nests with an underwater suction device ranged from 3,267 to 16,318 (mean, 8,002). The numbers of larvae similarly collected from two nests were 172 and 574.

Food, growth, and mortality of young largemouth bass.—We studied factors related to growth and survival of young largemouth bass and related species during high inflow and pool

elevation in Bull Shoals Reservoir during 1973. Regression analysis revealed that abundance of young-of-the-year largemouth bass from 1966–73 is highly correlated with both inflow and extent and duration of flooding of shoreline vegetation.

Extensive collection and examination of young largemouth and spotted bass following school break-up indicated large differences in growth of young of both species. These differences were related directly to the mode of feeding. Individuals that became piscivorous during the first 2 to 4 weeks after school break-up grew much faster than those which fed on invertebrates throughout the first summer of life. Faster-growing fish experienced a much lower mortality rate. Largemouth bass exhibited the greater tendency toward a piscivorous mode of feeding. Shad and brook silversides were the fish most frequently eaten.

Largemouth and spotted bass which did not become piscivorous displayed marked differences in feeding habits. Small largemouth bass fed primarily on limnetic cladocerans and copepods, whereas small spotted bass fed on littoral cladocerans and benthos. The early season variations in food habits suggest that largemouth bass utilize the open water habitat and spotted bass use the lake bottom. Food of the two species became similar after the seasonal decline of limnetic zooplankton in July. Growth of largemouth and spotted bass was similar on invertebrates diets, with both species showing slow growth after mid-July. Both species selected increasingly larger invertebrates as the size of the fish increased.

Abundance of the black basses.—Annual population estimates of abundance of the black basses in Beaver and Bull Shoals reservoirs are made with electrofishing gear. The measurements are useful in determining mortality and production patterns, and for evaluating angler use and harvest. Mark-and-recapture estimates are made on selected shoreline stations in the spring at stations in the upper and lower sections of each reservoir. During 1973, we also made a single estimate in the lower section of each reservoir to index over-winter mortality. In Beaver Reservoir, the largemouth bass spring estimate was 118 per mile of shoreline in the lower section and 728 in the upper. The estimate of spotted bass in the upper section

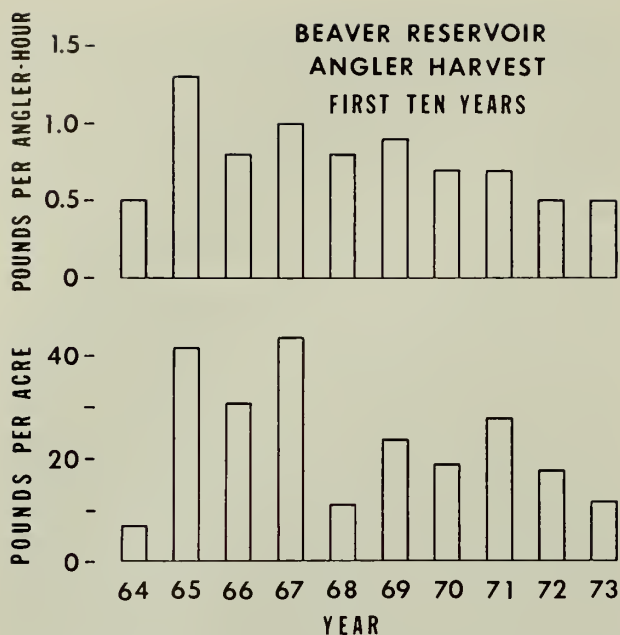
was 528 per mile. The fall estimate, including young-of-the-year, was 847 largemouth bass and 324 spotted bass per mile of shoreline. The spring estimates were dominated by 2-year-old largemouth and spotted bass, whereas the fall estimate was dominated by young-of-the-year largemouth bass and yearling and older spotted bass. Estimated biomass of largemouth bass in the lower section was 106 pounds per mile in the spring and 282 pounds in the fall.

In Bull Shoals Reservoir estimates of largemouth bass abundance in the spring were 64 per mile in the lower section and 43 per mile in the upper section. Spotted bass abundance in the upper section was estimated at 93 per mile. Reflecting the strong recruitment in 1973, the fall estimate of largemouth bass increased to 2,508 per mile. Biomass estimates of largemouth bass in the spring were 88 pounds per mile in the lower section and 50 pounds per mile in the upper section. The fall estimate was 1,570 pounds per mile.

Sampling of populations in coves.—We apply rotenone to selected coves in Beaver and Bull Shoals reservoirs annually to provide standing crop estimates and indexes of reproductive success of several fish species. Three coves (about 10 acres) are sampled on each lake and a weighted mean biomass is computed. The August 1973 total standing crop estimates were 528 pounds per acre for Beaver Reservoir and 326 pounds for Bull Shoals Reservoir. In Beaver Reservoir, the total standing crop decreased 39 pounds per acre from 1972, but young-of-the-year largemouth bass were five times more abundant—a phenomenon associated with high spring and early summer water levels.

The total standing crop estimate in Bull Shoals Reservoir was 215 pounds per acre greater than in 1972—a difference attributable to increases in threadfin shad, carp, redhorses, white bass, sunfishes, black basses, and crappies. Abundance of young-of-the-year spotted bass doubled and that of largemouth bass increased by 20 times, but young-of-the-year smallmouth bass remained relatively stable.

Angler harvest.—A 10-year summary of estimated angler harvest on Beaver Reservoir from impoundment in 1964 through 1973 (see accompanying figure) indicated a gradual decline in success-rate from 1.3 pounds per hour in the



Estimated angler success (top) and harvest rates (bottom) in Beaver Reservoir during the first 10 years of impoundment (1964-73).

2nd year to 0.5 pound per hour in the 10th year. Harvest of black bass was greatest in the 2nd year, when it reached 19.7 pounds per acre, with succeeding peaks in the 4th and 8th years of impoundment.

Estimates of angler harvest on Bull Shoals Reservoir in the 21st, 22nd, and 23rd years of impoundment (1971-73) indicated success rates of 0.34, 0.25, and 0.35 pound per hour. Total sport fish harvest estimates (10 to 13 pounds per acre) were near those recorded in Beaver Reservoir in the 10th year of impoundment. Black bass harvests were about 6 pounds per acre in both reservoirs in 1973.

Southeast Reservoir Investigations

The Keowee-Jocassee Reservoirs project.—The objectives of the Southeast Reservoir Investigations are to determine what effects the cooling water from a nuclear power station and a pump-storage project has on the fishes of the Keowee-Jocassee reservoirs. The collection of base line data for this investigation began in the spring and summer of 1972 before operation of these projects began. Unit number 1 (of a total of three) of the powerplant became operative in late spring 1973 and unit number

2 in November 1973. Both units were started and stopped several times for routine checks and to correct minor malfunctions, and it was not until the spring of 1974 that both units began producing power on a sustained basis.

Cooling water for the nuclear plant is taken from the depths of Keowee Reservoir where the temperature normally is about 10° C throughout the year. This water is heated about 15° C when passed through the plant and is discharged near the surface of the reservoir at about 25° C. During the summer of 1973 this heated effluent was cooler than the ambient reservoir surface temperature (usually above 26° C) and could not be detected at the surface. During the winter, however, when the nuclear plant was operating and surface water temperatures were cooler than the heated effluent, this warmer water could be detected for about 500 yards from the point of discharge.

The pump-storage project is designed to pump water from Keowee Reservoir (elevation 800 feet) to Jocassee Reservoir (1,110 feet) during periods of low power demand. During peak power requirements, this water will generate hydroelectric power through combination pump-turbine wheels as the water flows from Jocassee Reservoir to Keowee Reservoir. Jocassee Reservoir was filled by the fall of 1973 and this project began operations in December 1973. In February 1974, however, a leak was found in the Jocassee Dam, and pump-back operations were suspended while Jocassee Reservoir was lowered 30 feet to repair the leak. More recently, transformer problems have prevented power generation so that pump-storage operations have not functioned over lengthy periods.

The delay in full operation of the nuclear and pump-storage power projects has made possible the collection of base line data for about 2 years on Keowee Reservoir, but for only a few months on Jocassee Reservoir.

It is expected that water in the pump-back section of Keowee Reservoir will be cooler than the rest of the reservoir since water will be discharged into Keowee Reservoir from the cool hypolimnion of Jocassee Reservoir; conversely, it is expected that water temperatures in the nuclear plant area, at least in the winter, will be warmer than in other parts of the reservoir. Therefore, biological sampling areas

have been established in the pump-back area, the heated area, and in control areas in other parts of the reservoir farthest from the heating and cooling influences.

Fishes of Keowee-Jocassee Reservoirs.—Samples of fish have been collected for life history studies by trawl, seine, gill net, rotenone, and electroshocker. Four species—largemouth bass, black crappie, yellow perch, and bluegill—have been designated for studies on age, growth, reproduction, fecundity, and food. In 1972 and 1973 most of the largemouth bass captured were 3 years old or less. Black crappie ranged to 4 years of age, and yellow perch and bluegills ranged up to 5 years of age.

Juvenile and small fishes were captured at 20 locations in Keowee Reservoir from April through September 1973 with a small-meshed haul seine. Catches were dominated by whitefin shiner (59%) and bluegills (39%); also included were redbreast sunfish, largemouth bass, yellow perch, and 13 other species. More than 80% of both bluegills and redbreast sunfish were yearlings. Young-of-the-year fish do not appear in the seine until they attain a size large enough to be retained by the 3/16" mesh. Largemouth bass first appeared in catches in late May and bluegills in July, but whitefin shiner are not fully recruited to the seine until they are yearlings.

The experimental gill nets used in Keowee Reservoir were 150 feet long, and had consecutive panels of equal length of mesh sizes of 1, 1-1/2, 2, 2-1/2, and 3 inches. Catches by these nets from November 1972 through May 1974 consisted of silver redhorse (23%), carp (22%), flat bullhead (11%), quillback (11%), black crappie (8%), bluegill (8%), yellow perch (4%), brown bullhead (3%), largemouth bass (2%), chain pickerel (2%), and 10 other species (total 6%). The largest catches were made in April and May and the smallest in winter. Catches of carp, brown bullhead, bluegill, and golden shiner were highest in the south end of the reservoir, and decreased progressively toward the north end, whereas catches of silver redhorse, flat bullhead, quillback, and smallfin redhorse were highest in the north end and decreased progressively toward the south end.

Gill netting in May 1974 in Jocassee Reser-



Identifying and counting small fishes caught in a small-meshed seine to determine abundance and survival of new year classes. (Photo by G. B. Talbot)

voir produced 37% carp, 18% flat bullheads, 15% crappie, and 29% of 10 other species.

In cooperation with the South Carolina Wildlife and Marine Resources Department three coves in Keowee Reservoir totalling 10.5 acres and two 1-acre coves in Jocassee Reservoir were sampled with rotenone in 1972 and 1973. The South Carolina Department sampled smaller areas from 1968 to 1971 in Keowee Reservoir.

Carp have been the predominant fish by weight taken each year in Keowee, but their numbers are declining. Apparently carp reproduced only in 1968, the first year of impoundment. Other species that apparently produced one or more year classes while Keowee Reservoir was filling (1968-70), and very small year classes since 1971, include chain pickerel, golden shiner, brown bullhead, red-ear sunfish, and black crappie. Yellow perch reproduced significantly only in 1973. Standing crop for all species has ranged between 34.1 and 99.4 pounds per acre since 1968.

In Jocassee Reservoir the standing crop as determined from samples collected with rotenone, was 136 pounds per acre in 1972 while the reservoir was filling and 75 pounds per acre in 1973 when it was almost filled.

Sampling from a boat with the electroshocker has been carried out in three areas (each 2 miles long) along the shoreline of Keowee Reservoir each quarter. Twenty species were represented in the catches. Bluegills were pre-



Inserting a sonic tag into the body cavity of a large-mouth bass. The operation is done with surgical technique. The tag enables the movements of the fish to be recorded. (Iowa Cooperative Fishery Research Unit photo)

dominant (48%) with largemouth bass contributing 15% and carp and redbreast sunfish 10% each. Vulnerability of fish to electric shock has been shown to be directly proportional to body surface area, and our data show that fish smaller than about 4 inches are not taken. Also, catches appear to be related to water temperatures. Best catches were made near 11 to 12° C.

In Jocassee Reservoir, electroshocking was carried out in the fall of 1973 and spring of 1974. The combined samples contained 34 largemouth bass, 26 bluegills, 12 redbreast sunfish, and 19 fish of seven other species.

To determine the success of spawning each year, we towed a small-meshed frame trawl in four areas of the reservoir during the spring and summer at weekly intervals. Trawling was done at 0 to 4 feet and 16 to 20 feet. Larval sunfish, the most abundant group (48.4% of the catch), were captured between 14 May and 1 October 1973. Small yellow perch, which were next in abundance (41.9%) were caught from 13 March to 20 August. Black crappie (9.6%) were captured between 7 May and 17 September 1973. The rest of the catch consisted of various cyprinid fishes.

Bottom fauna and plankton of Keowee-Jocassee Reservoirs.—Four stations were established to monitor the bottom organisms found in Keowee Reservoir. These were sampled three times a year—April, July, and October.

Samples taken in October 1973 contained chironomids (47%), segmented worms (42%), and phantom midge larvae (11%). The chironomids were most abundant at depths to 20 feet, the segmented worms at 26 to 46 feet, and phantom midge larvae at 46 to 66 feet.

Sampling of zooplankton was carried out at five stations in Keowee Reservoir. Four 5-minute oblique tows were made from a depth of 50 feet to the surface at each station each month. These collections will help us to determine any differences that may result from heated effluent and pump-storage operations. To date, 42 species of zooplankton have been identified. Dry weights have varied from 40 to 80 mg/m³. These values are similar to those found on some Missouri River reservoirs in South Dakota and the White River reservoirs in Arkansas. Three plankton stations on Jocassee Reservoir have been sampled since June 1973.

Physical characteristics of Keowee-Jocassee Reservoirs.—Water temperatures, dissolved oxygen, conductivity, and water transparency readings were taken monthly at 10 stations on Keowee Reservoir. Temperature profiles in 1972 and 1973 were similar at all stations. The reservoir began warming in March and thermal stratification began developing in May and was completed by June. The thermocline was located between 13 and 26 feet in June and July, and then moved downward from August to a low point below 33 feet in October. Temperatures ranged from a low of about 7° C on the bottom in March to 28.4° C at the surface in July.



Boat equipped with transducer, receiver, and earphones to pick up signals from the sonic tag.

Oxygen values were ample for good fish survival over most of the year except at depths below 33 feet from August through October. Conductivity was low, varied little with depth, and ranged from 10 to 40 microhms per centimeter. Water transparency was highest in June and October and lowest in February.

Lowering the water level 30 feet in Jocassee Reservoir by discharging from a depth of 50 feet in February resulted in cooling of the upper end of Keowee Reservoir by about 1.4° C for a short period. Temperatures taken near the heated effluent site did not differ from those at other stations; however, the pattern of temperature with depth below the thermocline throughout the reservoir appeared to be changing from that found in previous years. Not enough data are yet available to determine if the heated effluent was the cause.

Similar information has been obtained from Jocassee Reservoir since January 1974. Reservoir warming, stratification, and thermocline

development were similar to that in Keowee Reservoir. Oxygen readings were adequate on the surface and to a depth of 100 to 130 feet, where the oxygen content began to decline rapidly.

Other studies on Keowee-Jocassee Reservoirs.—In addition to the research carried out at the Southeast Reservoir Laboratory, contracts have been negotiated with several other agencies. The South Carolina Wildlife and Marine Resources Department is carrying out a creel census in Keowee Reservoir to determine fishing effort and catch by time of year, species, and area. Clemson University has studies in progress on the effects of heated effluents on (1) the movement of largemouth bass (as determined by signals from sonic tags carried by the fish), (2) the well-being of caged catfish, and (3) the dynamics of zooplankton and freshwater insects. The University of Georgia is studying the fish populations of two small reservoirs receiving heated effluents.

COOPERATIVE UNITS PROGRAM

Cooperative Fishery Research Units

The first cooperative fishery unit program began at Utah State University under the leadership of Donald R. Franklin in 1962. Presently, there are 25 fishery research units in the United States. These unit programs are jointly supported by the U.S. Fish and Wildlife Service, State fish and game agencies, and universities. A written cooperative agreement among the supporting agencies exists for each unit. A coordinating committee composed of representatives of the aforementioned agencies meets at least once annually to establish overall planning and direction.

Day-to-day operations are the responsibility of the leader and assistant leader of the units. These personnel are Service employees and hold faculty positions at the host institutions. The university provides office, laboratory, and storage space and secretarial services. The States provide funds for support of graduate student thesis research.

Federal administration of the fishery unit programs was changed on 1 July 1973, from the Division of Fishery Services in the Regions to the Division of Fishery Research in the

Washington Office. In 1974, the Research Divisions were reorganized, and the units are now administered in Washington by the Division of Cooperative Research. Concurrent with this change, the major objectives of the unit programs were realigned to more fully utilize the research capabilities of the units. In order of priority the unit objectives are: research, graduate level training, and extension. Each of the 25 cooperative fishery research units has two fishery-aquatic specialists trained to conduct individual research and to supervise student research. The units are equipped to respond to cooperators' research needs.

During this reporting period, the staffs of the units have assisted universities by teaching approximately 75 formal courses and advising theses projects of approximately 300 graduate students. Unit staff, students, and cooperators published 225 technical articles addressing fishery resource problems. The units have provided cooperators with a variety of technical expertise and have addressed themselves to urgent fishery research needs.

The unit staff members have served on many special committees and task forces related to

enhancement and protection of the fisheries resources of the Nation. Examples of this assistance are: Leader, Georgia Cooperative Fishery Research Unit, served as Task Force Leader of Cross-Florida Barge Canal Study Team; Assistant Leader, Iowa Cooperative Fishery Research Unit, provided valuable testimony for the U.S. Environmental Protection Agency dealing with results of his pesticide research; Leader, Tennessee Cooperative Fishery Research Unit, established an intensive summer training institute in cooperation with TVA for minority students; Leader, Washington Cooperative Fishery Research Unit, was appointed by the U.S. District Court, Tacoma, to serve as a special advisor for the fisheries management of anadromous salmon stocks in the State of Washington.

Eight units (Iowa, Massachusetts, Montana, Ohio, North Carolina, Utah, Virginia, and Wisconsin) now have study contracts with the U.S. Fish and Wildlife Service on stream alteration research.

Unit staffs serve the professional societies well. During the reporting period leaders or assistant unit leaders held three of the four Divisions' presidency chairs of the American Fisheries Society.

Of the unit students graduated during the reporting period, about 125 became permanent full-time employees in the natural resources field. Most students were hired by public agencies, although some were hired by private industry.

Auburn University, Auburn, Ala.—The Unit personnel are engaged in the following studies: systematics (faunistic, taxonomic, zoogeographic, and cytogenetic); ecology (rare or endangered species, small streams, large rivers, and reservoirs); reproduction (sex reversal and induced spawning); and fish importation. Unit research projects completed during this reporting period include one faunistic survey, two taxonomic studies, two studies of movement in streams and reservoirs, one sex reversal study, and one study concerning a rare species.

In the sex reversal study, 1-dehydrotestosterone acetate (DHT), Ethisterone (ET), and 17 α -methyltestosterone (MT) were fed at various dosage levels for 18 days to sexually undifferentiated *Tilapia aurea* fry. Tilapias are an important food fish in many developing

countries but have the tendency to overpopulate and thereby reduce the yield of harvestable size fish. Monosex culture is one method of eliminating this problem.

Feeding in tanks neither affected survival nor altered growth. Treatment with ET and MT at all dosage levels resulted in significantly higher percentages of males than no treatment. Only males were produced with ET at the highest level. Progeny testing indicated functional sex reversal had been achieved. This technique appears to have the potential of producing monosex populations at a low cost and on a commercial scale.

University of Arizona, Tucson.—The Arizona Unit is currently involved in a variety of field and laboratory studies. Because water is so scarce in Southern Arizona, one of our major research goals has been to develop management potential for all types of water. One such study, "Sport Fish Production and Productivity Relationships in Reclaimed Domestic Wastewater," was to evaluate the suitability of reclaimed domestic wastewater for a sport fishery. The water was reclaimed by a tertiary treatment of sand filtration. The fish tested were channel catfish, rainbow trout, and *Tilapia* hybrids. The major objectives were to establish survival rates, growth rates, stocking schedules, and maximum stocking densities for these fish in an unusual and highly productive environment. Survival was less than 1% in five trout experiments and in one catfish experiment. The major cause of mortality was low oxygen tensions at sunrise resulting from respiration of dense phytoplankton blooms which were stimulated in part by high (14 mg/l) average inflow of orthophosphate concentrations. When fish survived, production was high. The total yields of acceptable channel catfish and *Tilapia* were 383 and 397 kg per hectare, respectively. *Chironomus* larvae, the predominant food organism, composed 90% of the estimated annual benthic production of 12,656 pounds per acre. Zooplankters, although abundant, were not an important source of fish food because of their small size. Production of oxygen by phytoplankton averaged 10.2 g per m³ per day. The present waters, although highly productive, cannot be expected to support a dependable fishery because occasional unfavorable oxygen conditions are likely to reoccur.



Colorado Fishery Research Unit student removes otoliths from lake trout head. The effects of operating a pumped storage hydroelectric generating plant on the life history of lake trout is being studied at Twin Lakes, Colo.

Humboldt State University, Arcata, Calif.—The Unit completed several research projects which involved both marine and freshwater habitats. A 3-year study of the effects of chronic oil or oil dispersant pollution on marine fish demonstrated changes in the serum proteins and effects on the reproductive biology of the test fish, a seaperch. A second pollution study of the acute toxicity and the chronic effects of road oil, used to control dust on logging roads, on juvenile salmon revealed an effect on feeding behavior and an increased susceptibility to disease.

Other projects completed were a study of the kinds and abundance of marine colonizing organisms on various materials used to construct artificial reefs; an investigation of feeding competition between juvenile steelhead and roach in the Eel River, an important anadromous stream; and a study of the food habits of rain-

bow trout in a trout stream from which nongame species had been removed.

Colorado State University, Fort Collins.—An experimental urban fishery established by stocking marked channel catfish in the once heavily polluted South Platte River proved disappointing. City residents of Denver did not avail themselves of the fishery apparently because of the unaesthetic surroundings and persisting episodes of pollution. Survival and residence of catfish in the river was less than a year.

Environmental evaluations in Yellowstone and Rocky Mountain National Parks revealed subtle but significant changes in plant and animal communities of several lakes and rivers due to dumping of sewage or to recreational use of the watersheds. A similar baseline study was done on the invertebrate community of the South Platte River in anticipation of using the



Unit students gingerly collect a poisonous scorpion fish on a Waikiki reef during an ecological study of Hawaiian reef fishes. Because of the large, toxin-bearing dorsal spines, Hawaiians call it "nohu," meaning "trouble."

river water as a coolant for the St. Vrain nuclear generating plant.

Further classification and distributional studies of cutthroat trout of the Rocky Mountains have aided in the identification of trout populations whose genetic purity has not been significantly altered by hybridization. This information is being used to designate populations to be preserved as rare and endangered or threatened.

Studies have indicated that it is feasible to rear rainbow trout in natural lakes by the cage culture method. Experiments have also disclosed that largemouth bass can be reared on artificial diets but they require a higher protein and fat level and more complete comple-

ment of vitamins than trout. It was also learned that heavier largemouth bass fingerlings accepted pelleted diets more readily than those of equal length but less weight.

University of Georgia, Athens.—The emphasis of the Unit's research program is diverse, but generally involves small pond management, reservoir investigations, and the effects of habitat alterations on the aquatic system. Thirty ponds and lakes which range in size from 3 to 150 acres located at Fort Gordon are used for management studies. A series of cooling reservoirs at the Atomic Energy Commission's Savannah River Plant are used for thermal effects studies. The Unit also works closely and has a number of cooperative projects

with the Georgia Game and Fish Division. During this period the Unit has been involved in 18 research projects of which 8 have been completed.

The Unit participated in two extension courses. Approximately 200 Georgia Wildlife Rangers (20 at a time) attended a course on farm pond construction and management, and water pollution. Sixty U.S. Corps of Engineer employees attended a recreation-resource management program. The Unit contributed information on reservoir biology and management.

The Unit has participated in special assignments. The Unit Leader served as a Task Force Leader on the Florida Barge Canal Impact Study. The Assistant Leader served as President of the Southern Division of the American Fisheries Society and on the Steering Committee for the National Bass Symposium. Both are active on other committees for a number of scientific organizations.

University of Hawaii, Honolulu.—The uniqueness of Hawaii's fragile insular environment and man's influence on it provide a central theme for the Unit's research projects. Continued habitat deterioration associated with expanding population and development pose increasing threats to the already impoverished native fauna, especially in coastal and stream waters.

Recent and current student research topics mainly concern aspects of the biologies of Hawaiian crustaceans and fishes. Staff-level programs, some involving other agencies, feature environmental surveys of inshore marine and inland waters to recognize areas of high natural quality for protection as underwater parks or as native ecosystem reserves. One example is the recently completed survey of 318 coastal ponds on Hawaii Island—small exposures of water in recent lavas that contain unusual fauna and represent a heretofore unrecognized class of aquatic ecosystem. Another example is the limnological investigation of the State's two remaining natural lowland lakes, both in craters and one having the remarkable depth of 815 feet. A third example is the extensive survey of inshore waters to determine the diversities of reef fishes and benthic fauna in preparing a list of candidate marine park sites.



A student at the Idaho Cooperative Fishery Research Unit is studying the effects of water temperature on the behavior of juvenile steelhead trout in experimental channels.

Other marine studies concern the ecology and zoogeography of Hawaiian reef fishes. Investigations on commercial exploitation of colorful reef fishes for the growing aquarium trade indicate that three species occupy 60% of Hawaii's catch of aquarium fishes which has an estimated annual retail value exceeding \$200,000. Preliminary evaluation of importation permits show that 10 times as many live foreign reef fishes enter the United States through Hawaii than are caught locally. These studies are intended to provide a basis for regulations to conserve Hawaii's diminishing reef fish resource.

University of Idaho, Moscow.—Management and ecology of salmonids was the primary focus of research by the Unit. A study of the response of the cutthroat trout population in the upper St. Joe River to special angling regulations (3 fish limit; minimum size 13 inches) revealed that both the abundance and mean size of cutthroat trout increased. Abundance doubled in some test sections and average size of cutthroat trout in the population increased by 2 inches from that observed at the beginning of the



The uptake and elimination of dieldrin by channel catfish is being evaluated at the Iowa Cooperative Fishery Research Unit.

study in 1969. No corresponding increases were observed in sections of the river with standard fishing regulations. A sharp decline in fishing effort occurred during 1971 when the special regulations were put into effect, but effort had increased to pre-1971 levels by 1973. Anglers caught five times more cutthroat trout in 1973 than in 1968 but kept only one-third as many.

Long-term assessment of salmon and steelhead production and yield in Lemhi Big Springs Creek continued. In 1973, 853,000 steelhead fry were stocked in Big Springs Creek to compare the yield of steelhead stocked alone at a density equal to the density of steelhead and chinook salmon stocked together in past years. During the fall of 1973, 28,881 age-0 steelhead migrated downstream after rearing for the summer, compared with a previous maximum of 21,900 in 1967. In 1972, when 358,200 steelhead fry and 291,000 chinook salmon fingerlings were stocked in the creek, 15,380 steelhead and

56,600 chinook salmon migrated from the stream during the fall. The stream yielded the largest total number of 0-group fish when both steelhead and chinook were stocked simultaneously.

Effects of sediment on juvenile steelhead and chinook salmon in both summer and winter habitats were evaluated in another study. Neither species was affected by levels of batholith sediment added to riffle sections during summer but a reduction of pool area by sediment brought about a decrease in the number of fish present in pools. Under winter stream conditions, fewer age-0 steelhead and chinook salmon remained in sedimented riffle sections than in riffles without sediment.

Iowa State University, Ames.—A Fish and Wildlife Service research contract was initiated to investigate the effects of stream alteration on game fish populations in midwestern United States. Iowa Unit and University staffs joined in a cooperative study to inventory altered streams in Iowa, measure the effect on game fish of short-reach highway projects and long-reach channelization, and to evaluate stream control and bank-stabilization structures. On the basis of aerial photographs, 85% of the current length of streams draining more than 50 square miles in the Missouri River drainage in Iowa are in a straightened condition. The percentages of stream miles straightened are 70.5% for the Des Moines River drainage and 76.6% for the Skunk River drainage.

Iowa farmers have used an estimated 5 million pounds or more of aldrin per year in 1961–65 and 2 million pounds per year in 1968–73 to control corn rootworm and other corn insects. Aldrin, changed to dieldrin, is finding its way into Iowa surface water and in turn levels of dieldrin as high as 1.6 ppm have been detected in edible portions of channel catfish. Measurement of dieldrin concentrations in Des Moines River water from April to October, 1971–73 ranged from 1 to 50 ppt. Dieldrin levels were highest in June and July, and peak levels occurred within a month after aldrin applications at corn planting time. Dieldrin levels in aquatic insects and minnows sampled in 1973 were highest in June. Peak levels in muscle tissue of channel catfish occurred in July for most size groups. Dieldrin levels in catfish muscle varied with size and age of fish, but not

with muscle fat. Biomagnification of dieldrin from catfish food organisms to catfish muscle tissue was not evident. In laboratory studies, large catfish accumulated more dieldrin than did small catfish in a 28-day water exposure, but the large fish eliminated dieldrin more rapidly once exposure ceased. When catfish were exposed to dieldrin in food and water, dieldrin from both sources contributed to the total dieldrin load, but more dieldrin was accumulated from water than from food at the levels tested (75 ppt in water vs. 2 ppm in food).

Louisiana State University, Baton Rouge.—Research was divided into 15 projects under one of four major divisions: A survey of seasonal changes in the water chemistry, plankton, benthos, and fishes of a segment of the lower Mississippi River for baseline data before nuclear powerplant construction; a similar survey of the Atchafalaya River (to predict the effects of various alternative water manipulation plans); miscellaneous studies on smaller freshwater bodies; and ecological studies of juvenile estuarine-dependent organisms.

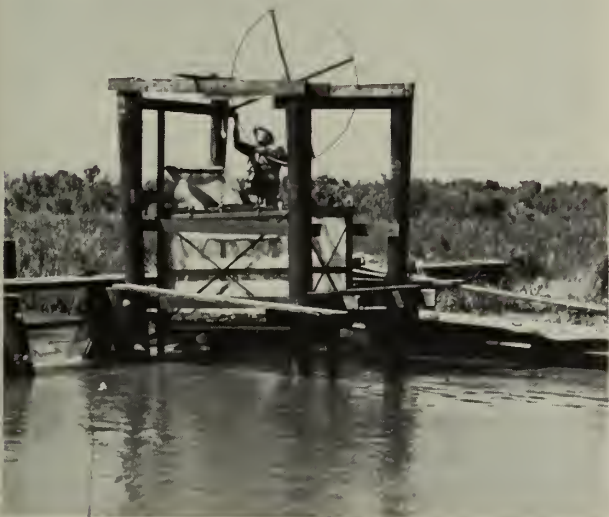
Much information of both scientific and immediate practical value has been gained from these studies. For example, evidence is being acquired that some current beliefs are incorrect concerning the juvenile life history of estuarine-dependent organisms; the company building a



Juvenile Atlantic croakers are marked en masse to study their growth rate. The marker is fluorescent pigment implanted in the fishes epidermis and external hard structures with a sandblast gun.

nuclear powerplant changed their plans to include cooling towers when Unit studies showed excessive thermal pollution would result from returning reactor cooling water directly to the river; and specific water management advice for Atchafalaya Basin floodway waters have been forwarded to the U.S. Army Corps of Engineers, as a consequence of a holistic study of the Basin's aquatic communities.

University of Maine, Orono.—Test introductions of landlocked alewives in three Maine lakes produced variable results. Alewives failed to survive the first winter in Gould Pond; an unstable but reproducing population was established in Echo Lake; and a population tending toward stability exists in Silver Lake. Growth of alewives in Echo Lake greatly exceeded that of the donor population. Growth rate in Silver Lake was less than in Echo Lake but greater than the donor population. Young-of-the-year alewives were extensively utilized as forage by landlocked salmon, especially during the summer and fall. In a laboratory preference study, landlocked salmon fed an alewife diet preferred the odor of alewives to that of smelt; salmon fed on smelt had no preference between smelt and alewife odors; and salmon fed on both species preferred alewife odors. Odor preferences could be conditioned in as little as 4 days and they disappeared 5 weeks after withdrawal of the stimulus.



A trap for capturing marked fish and other aquatic organisms moving through a marsh nursery area is used in a Louisiana Unit study.

Efforts to cryopreserve Atlantic salmon sperm have not been successful. The best hatching rate of eggs fertilized with cryopreserved sperm was 1.5%, well below acceptable levels for hatchery application. Detailed description of salmon ultrastructure was completed. Damage during freezing and thawing generally involves membrane destruction. Ott's diluent provided some protection from damage, but not enough to ensure a reasonable number of spermatozoa capable of fertilization. Mature salmon gametes retained 80% viability after 3 days storage on crushed ice. Viability dropped to 20% after 5 days.

Density of egg deposition by anadromous rainbow smelt was correlated with water velocity, distance from the ocean, water temperature, and available spawning time. Hatching success was lower for smelt eggs incubated

on sand than for those incubated on gravel or on an artificial substrate.

Striped bass from six east coast locations and from California have been screened for enzymatic variation. Only two of eight enzymes studied were polymorphic. Hudson River striped bass differed from Chesapeake Bay populations whereas California bass lacked genetic variation at any tested locus.

Angler harvest and standing crop estimates made on a 2,035 acre warmwater lake in central Maine indicated that a population of approximately 2,200 smallmouth bass was sustaining itself under a harvest rate of 0.5 fish per angler hour. Production of juveniles was reduced about 10% by a 10-inch drop in water level during the period of nest guarding. Large males were more successful at guarding than were small males. The lake had a standing crop of 80,000 white perch which were harvested at a rate of 3 per angler hour. Standing crop of yellow perch was 0.59 pound per acre and growth was slow; 78% of the age-I fish were sexually mature at a mean length of 2.7 inches.

University of Massachusetts, Amherst.—The Unit devoted considerable time collecting data on the behavior of adult American shad in the Connecticut River above the Holyoke Dam, Mass. Sonic tagging of adult shad yielded information on swimming speeds, migratory patterns as they pass by specific locations (i.e., proposed or existing powerplant sites), and shad behavior during the Northfield hydroelectric plant pump/discharge cycle. Various environmental characteristics associated with adult shad movement at the Holyoke powerplant fishlift were statistically evaluated to determine what factor or combination of factors trigger their migration through this complex system. Shad egg drifting rates under different flow conditions and distribution of eggs at a specific spawning site have been established. Finally, discrete shad spawning sites between Holyoke and Turners Falls dams were utilized for the past 3 years. An attempt was initiated during the 1974 spawning run to statistically sample five of these sites and rank them in terms of egg production.

Research on the anadromous alewife in the Parker River has been underway since 1971. Biological data on population size, sex ratios,



A fishladder designed for the passage of alewives in the Parker River. These anadromous fishes are being studied at the Massachusetts Cooperative Fishery Research Unit.



Comparative size of esocid fish after one season of growth in experimental ponds. The fish are (from top to bottom) muskellunge, northern pike, and tiger muskie (F_1 hybrid).

age and growth, and mortality are being gathered for both the spawning adults and young-of-the-year to help resource agencies optimize management plans.

University of Missouri, Columbia.—The primary goal of the Unit is to develop optimum sustained yield as a principle of fishery management. Optimum yield in sport fisheries is related to the quality of fishing and in commercial fisheries to profit.

From 1 January 1973 to 30 June 1974 most research was conducted on ponds and small reservoirs to evaluate various species for stocking strategies. Smallmouth bass, when combined with largemouth bass in ponds, had lower growth and survival than when planted alone. Smallmouth bass production was directly related to water transparency and alkalinity. Red-ear sunfish alone provided insufficient forage to support adequate bass production, but showed value as an additional panfish species

in pond management. Florida largemouth bass suffered high winter mortality and poor growth in Missouri ponds. White amur reduced plant density, improved water quality, and benefited production of bluegills and fathead minnows. Of muskellunge, northern pike, and hybrid tiger muskie stocked at equal densities, the tiger muskie had best growth and survival, and appears most suitable of the esocid predators for warmwater reservoirs. Freshwater shrimp significantly increased the growth rate of bluegills, and warrant further research as a forage invertebrate in pond management.

Laboratory studies indicated that light intensity was of secondary importance in catfish production when compared to disease, water quality, and nutrition. Low food availability for adult bluegills did not deter reproduction and recruitment of small bluegills; recruitment appeared inversely related to densities of adult bluegill.



An experimental "scoop" net is being developed at the New York Cooperative Fishery Research Unit for obtaining large samples of small fish in ponds with minimum damage to the fish or their habitat.

Environmental studies were aimed at toxicants and thermal effluents. Treatments of rotenone and Antimycin A at 20 ppm and 40 ppb had no effects on abundance and species diversity of pond zooplankton and benthos. Thermal effluent into Thomas Hill Reservoir, a 4,500-acre cooling-water impoundment, had no apparent detrimental effects. The effluent created a popular winter fishery for largemouth bass and crappie in the immediate area of its outfall.

Montana State University, Bozeman.—A great amount of mining and milling of heavy metal ores has taken place in Montana. In several areas of the State, water now seeps through the shafts and spoil piles of inactive mines and through the tailings of unused mills acquiring sufficient concentrations of heavy metals to pollute nearby streams. Studies were undertaken to assess the extent of this type of pollution in two drainages in Montana. Water percolating through a "reclaimed" tailings pile adjacent to Soda Butte Creek accumulated high concentrations of total iron and sulfate and altered the community of aquatic insects in the creek for at least 1-1/2 miles below its point of entry. Water seeping through mine shafts and spoil piles on the banks of Galena Creek accumulated high concentrations of zinc, copper, sulfate, and iron. Upon entering the creek, it caused a severe reduction in the numbers and kinds of aquatic

insects and killed fish in a bioassay over a stretch of 13 miles of stream.

The channelization of streams is a widespread practice used to accommodate construction activities, flood control projects, and agricultural expansion. The effects of channelization on the trout populations of the St. Regis River, Montana, are being studied under a contract with the Fish and Wildlife Service. Preliminary results show channelization generally decreases the numbers and standing crops of trout, and rock current deflectors have some mitigating effects.

The paddlefish support an important fishery in the lower Yellowstone River in Montana. A project was undertaken to obtain knowledge of their biology to better insure the continuance of the run. The difficulties of tracking radio-tagged fish over large reaches of extremely turbid and turbulent water have been overcome and paddlefish movements are now being monitored from a small plane.

Cornell University, Ithaca, New York.—A major segment of the Unit's research program is directed toward understanding the causes of mortality in eggs and young of freshwater fishes. One series of experiments showed that the survival of incubating largemouth bass eggs decreased sharply when dissolved oxygen levels were below 2.0 and 2.8 ppm at water temperatures of 15 and 25° C, respectively. At oxygen levels between 2.0 and 7.9 ppm, survival of bass eggs was markedly lower if the water surrounding the eggs was not circulated occasionally (as is accomplished by fanning activities of the guarding male parent). In a 12-day experiment with walleye larvae initially 2 days old, three constant and three variable temperature regimes within the range of 10 to 16° C did not affect survival, but the higher temperatures produced faster growth. Muskellunge larvae, reared in an environment devoid of plankton or other food organisms until they became free-swimming postlarvae, survived and grew as well as those that had been exposed to plankton throughout the prolarval (yolk-sac) stage.

A gas-operated jet inoculation apparatus was found to be highly effective for marking fish as small as 3 inches by injecting the fins with conspicuous dye spots. A new type of net was developed for obtaining very large samples of the populations of young fishes in 0.1-acre



This haul seine brings in a catch of river herring from a coastal river in North Carolina.

ponds, with minimal injury to the fish involved.

A mail-questionnaire survey for evaluating fishermen preferences was developed and sent to a random sample of 1,100 residents in the Owasco Lake (New York) basin. Data from the 800 (75%) returns indicated that mail-questionnaire surveys can accurately estimate fishermen preferences on a local or regional basis, and thus provide a means for sportsman input to the formation of fishery management policy.

During the past year a comprehensive program in aquaculture was established by Cornell University. The program is unique in the diversity of expertise which can be focused upon various aquacultural problems by the participating departments, colleges, and cooperating agencies.

North Carolina State University, Raleigh.—Four separate research contracts on the effects of stream channelization on fish and wildlife populations have been awarded the Unit. Three of the contracts involving the Water Resources Research Institute, the Division of River Basins, and the Soil Conservation Service terminate in 1974. Field research for these contracts has been completed.

A contract with Carolina Power and Light Company to evaluate fish movements in and around a nuclear powerplant site at Southport has been under way for a year. The main thrust of this research involves sonic tracking with transmitters placed in and on suitable fish of various species.

Research continues on the selection and breeding of warmwater fishes. Selection experiments with channel catfish and bluegills highlight this research project. Three manuscripts from this work have been submitted for publication. Work is under way with a karyotype analysis of the family Ictaluridae and tissue culture techniques for obtaining chromosome spreads have been successfully developed.

Hybridization work within the family Centrarchidae and work on the inheritance of color patterns in bluegills also continues.

Ohio State University, Columbus.—In a temperature preference study, four species of fish (emerald shiner, white bass, smallmouth bass, and yellow perch) from western Lake Erie were tested in a horizontal temperature gradient for 2 to 3 days during each of four seasons. Differences in seasonal temperature preferences were attributed to acclimatization in the Lake.

Selected temperatures of fishes in the horizontal gradient allowed predictions on temperature selections in a thermal discharge plume in the Lake. Temperatures selected were above ambient lake temperatures except for emerald shiners in summer and autumn. Except for yellow perch, the fishes had a relatively narrow temperature range in summer and a larger range of selected temperatures during other seasons. Emerald shiners selected a narrow range of temperatures at all seasons. Differences in temperature selections between young and adults within a species were noted in spring and autumn when lake temperatures were changing rapidly.

Compressed air systems were used to destratify a quarry pond 59 feet deep. Destratification attempts were unsuccessful in maintaining a combination of oxygen concentrations (5 mg/l) and temperatures suitable to rainbow trout. Hypolimnetic aeration without destratification was attempted with a 2-hp airlift pump and a hypolimnion tube. The entrained hypolimnion water was saturated with oxygen but circulation was insufficient to raise dissolved oxygen levels.

The direct addition of oxygen to water pumped from the hypolimnion and returned to the hypolimnion yielded significant results. Dissolved oxygen levels were increased linearly from 0.5 to 8.0 mg/l during 2 months of oxygenation. After oxygenation was terminated oxygen declined 1 mg/l per week until autumn overturn in late October. Oxygenation is expensive but may be a satisfactory means of restoring fish habitat to the anaerobic hypolimnion of a lake.

Oklahoma State University, Stillwater.—The Unit completed the second year of a study of the efficacy of diuron as a herbicide for control of pond weeds. Biomass of aquatic macrophytes were measured before and after application of the diuron in each of the 2 years.

The Unit examined the feasibility of using dried paunch (the rumen contents of cattle) at 10, 20, and 30% levels in sinking, pelleted feed for pond-rearing of yearling channel catfish, and at 10% in a floating, extruded pelleted feed for cage-culture of yearling fish. Paunch is a mixture of gastric juices, microbial flora, and the remains of the partially digested food. In slaughterhouse effluents, fresh paunch has

been a serious water pollutant. This study was aimed at providing an economic incentive for marketing dehydrated paunch as an ingredient for animal feeds. There was no significant difference in final weights attained by pond-reared fish given standard, 10, and 20% paunch feeds, but fish given 30% paunch were significantly smaller.

Studies were continued on largemouth bass population dynamics in a 3,300-acre reservoir. Efforts were concentrated on measuring year-class strength, seasonal growth of young-of-the-year bass, and methods for measuring year-class strength during the first summer of life.

The Unit produced a completion report for Oklahoma Federal Aid Project F-31-R-2. The report dealt with aspects of man-days fisherman use, fish harvest, and expenditures per man-day on the remaining flowing portions of the Mountain Fork River above and below Broken Bow dam. There were no significant differences in man-days use above and below the reservoir. Although fish harvest above the reservoir was significantly greater than below, the upstream harvest was affected by migrations of reservoir fish. Fishermen above spent \$9.13 per man-day and fishermen below spent \$9.91 per man-day. The value per man-day below was affected by the presence of an adjacent State park and by recreational facilities constructed by the U.S. Army Corps of Engineers. The capitalized value of the remaining lotic portions of the river was \$3,167 per mile above and \$3,877 per mile below the reservoir (\$1,762 per mile below excluding the State park area).

Oregon State University, Corvallis.—The Unit's research program during 1973-74 included studies of trout population dynamics, fish behavior, genetic variability of fish stocks, and effects of pollutants on selected fishes. The majority of the Unit's research activities were directed to the improvement of anadromous fish stocks.

From studies completed during 1973-74, it was concluded that mortality in fish populations caused by their exposure to heavy metals, or to air supersaturated water below dams, may produce changes in their genetic make-up. These genetic changes can produce an increased average resistance to the lethal effects of these pollutants. For instance, it was demonstrated that for genetic reasons, fall chinook salmon



South Dakota Cooperative Fishery Research Unit students seining walleye from prairie pothole rearing pond.

from the Columbia River are more resistant to the effects of air supersaturated water than are fall chinook from an Oregon coastal stream on which no dams have been constructed.

Results of other studies indicated that selective breeding can increase survival of artificially propagated salmonid fishes during the hatchery- and ocean-rearing periods of their life cycle. Experiments are now under way to confirm these results.

Pennsylvania State University, University Park.—Investigation continued on various aspects of the behavior of fish, particularly concerning their use of space and cover. A study on the effect of low dissolved oxygen levels on cover-seeking behavior of smallmouth bass revealed that nonlethal but low levels of dissolved oxygen could be detrimental to smallmouth bass populations because of increased activity and decreased use of cover, thus necessitating a greater expenditure of energy and consequent need for food. Current dissolved oxygen standards for smallmouth bass may not be high enough to assure long-range protection of natural populations.

Another study showed that cover-seeking behavior in brook trout is genetically controlled, at least in part. This knowledge could be useful in breeding trout for stocking in streams.

Research continued on the relative effects of chemical and mechanical weed control on the

ecology of a recreational reservoir. Both methods were effective for controlling weeds, but the mechanical harvesting method has the advantage of removing nutrients (which promote weed growth) from the system. Relative effects on the fish population are not yet clear but weed control does improve fishermen's enjoyment.

A creel census indicated that legal-size trout stocked in a reservoir contributed to the fishery only during the first 3 to 4 weeks of the season. There was little carryover from year to year.

Work continued on production of a documentary film on the ecology of a mountain stream during four seasons, in cooperation with the University of California's Sagehen Creek Field Station.

South Dakota State University, Brookings.—Nutrient enrichment of surface waters results in excessive algae blooms and fish kills in the northern plains. The origin and transport of nutrients in the upper and central regions of the Big Sioux River were studied from November 1971 to November 1972. The drainage area of the upper region was 526 square miles of primarily agricultural land and 3 square miles of municipality. Agricultural land contributed 2,730,756 pounds of organic carbon, 242,570 pounds of organic nitrogen, and 186,450 pounds of phosphate. The municipality contributed 356,114 pounds of organic carbon, 74,646 pounds of organic nitrogen, and 127,138 pounds of phosphate. Approximately 90% of the organic carbon, 87% of the organic nitrogen, and 67% of the phosphate was attributed to the agricultural drainage areas.

Primary production, chlorophyll content, phytoplankton species composition, and nitrate concentrations were determined from June 1973 to 1 July 1974 for Lake Poinsett, the largest natural lake in the Big Sioux River drainage. Analysis and interpretation of data are near completion.

A creel survey was conducted on Lake Sharpe in central South Dakota from 11 May 1973 through 31 May 1974. There were 71 airplane flights made to obtain an estimate of fishing pressure and 187 ground surveys made to obtain an estimate of catch rate, fishing methods, and angler residence. Preliminary analysis of the data indicates that fishing pressure had dropped at the Lake Oahe Dam



South Dakota Cooperative Fishery Research Unit students releasing pothole reared walleye into Lake Poinsett.

tailwaters since 1959–67. Lake Sharpe had the highest fishing pressure and the Big Bend Dam tailwaters had intermediate fishing pressure. The highest catch rate recorded was 0.98 fish per hour at the West Bend area of Lake Sharpe in June 1973.

Food habits, growth rate, and removal methods for walleyes reared in a 30-acre marsh were studied in 1973. The average total length and weight of walleyes increased from 1.7 inches and 0.02 ounce on 5 June to 6.6 inches and 1.5 ounces on 13 September.

A study of paddlefish culture methods revealed that paddlefish could be successfully reared at the Gavins Point National Fish Hatchery in water temperature of 18.3° C, but they suffered total mortality at the Unit's laboratory in water temperature of 10.0° C.

Test netting in Unit culture ponds indicate that 1-day-old fry stocked in the ponds survived and attained 6 inches total length in 6 weeks.

Corixids (Water Boatmen) collected in August from 43 lakes, 28 marshes, and the Big Sioux River of the South Dakota Glacial Lake District indicated distinct differences in habitat type and species composition. Life histories and densities of corixids and food habits of littoral zone fishes indicated that corixids were not used as food and that fish exerted no appreciable amount of influence on life histories or densities of corixids.

Tennessee Technological University, Cookeville.—Imported bait fishes are a possible source of new fish diseases and parasites in Tennessee. A 1-year survey was conducted to determine what parasites and diseases are associated with

bait fishes from a large commercial dealer in the State. Thirteen taxa of parasites were found, all of which are already present in Tennessee. Two species of pathogenic bacteria, *Aeromonas liquefaciens* and *Chondrococcus columnaris* were the only bacteria identified, both of which are common in the State.

Crappie populations in Tennessee reservoirs are generally underutilized by anglers. Stake beds, a type of attractant, have been successful in the relatively shallow main-stream reservoirs, but have not been tried in the deeper storage reservoirs where water levels fluctuate widely. A study of the effectiveness of stake beds in Center Hill Reservoir, a storage impoundment, indicated that they are probably ineffective in attracting crappie in large numbers in that reservoir.

Larval and adult fishes were collected weekly in the spring and summer of 1974 from Nickajack Reservoir near the vicinity of the Raccoon Mountain Pumped-Storage Project, now under construction by TVA (Tennessee Valley Authority). Species composition and relative abundance were determined by gillnetting and electrofishing. An age and growth study of the bluegill was included. Larval fish collections demonstrated distribution differences of species in the Reservoir and showed peaks in abundance during the spring and summer until the fish were large enough to avoid the meter net.

Utah State University, Logan.—Most of the Unit program emphasis can be grouped under the following headings: (1) genetic studies of fish populations; (2) responses of fish populations to alterations of the aquatic environment; (3) behavior and habitat requirements of fish and aquatic invertebrates; (4) manipulation of undesirable fish populations; and (5) rare and endangered species.

In the genetic studies of fish populations, two electrophoretic forms (phenotypes) of lactate dehydrogenase (LDH) were discovered in blood serum of a group of Beity strain domestic rainbow trout. Experimental crosses showed that the atypical phenotype was the heterozygous form between the normal LDH locus (B^2). Several tissues yielded the same LDH phenotype as was present in blood serum. The variant was electrophoretically the same as one reported in anadromous steelhead trout. Activation of the paternal LDH gene occurs before hatching.

There was no differential mortality among LDH phenotypes.

The studies of rare and endangered species included a description of the status of the fish fauna in the upper Colorado River basin where four endemic species—Colorado squawfish, bonytail chub, humpback chub, and humpback sucker are rare and endangered. Introduced species outnumbered native species 19 to 10. Areas that supported reproduction of the four rare species included the lower Yampa River, Desolation Canyon of the middle Green River, and the lower Green River in Canyonlands National Park. Major reasons for the decline of the native fauna were considered to be alteration of habitat by high dams and introduction of exotic species.

Virginia Polytechnic Institute and State University, Blacksburg.—The Unit is currently conducting research in three major areas and is participating in studies directed by co-operators with the Army Corps of Engineers and the West Virginia Department of Natural Resources.

One major research effort, funded by the Fish and Wildlife Service, is to determine the effect of stream channelization on fish and wildlife resources. The Unit, in cooperation with the Virginia Cooperative Wildlife Research Unit and Soil Conservation Service, is evaluating the impact on fish and wildlife of channel work completed 1 to 12 years ago. Another aspect of this study is to compare actual with projected cost-benefit ratios.

The Unit is also evaluating the effects of artificial reefs in a reservoir. This study is funded by the Virginia Commission of Game and Inland Fisheries and has the cooperation of Bassmasters and Appalachian Power Company. Preliminary analysis suggests that artificial reefs can improve bass and bluegill fishing in previously low productive areas.

The Unit is nearing completion of a contract with the Appalachian Power Company to evaluate the effects of pump-back storage on spawning of bass and bluegills. Large fluctuations in water levels associated with pump-back operations may be detrimental to bass and bluegills spawning in the shallow water. Preliminary data indicate bass and bluegills spawn at deeper than normal depths and thereby successfully hatch young.

University of Washington, Seattle.—During the summer of 1973, the Cooperative Fishery Research Unit and the Wildlife Recreation Research Unit of the United States Forest Service undertook a joint study of certain highland lakes in the Cascade Mountains of Washington State. Their purpose was to collect and evaluate information on both the lakes and the people who frequent them. The Cascade Mountains, and particularly the Alpine Lakes area in which the highland lakes are located, constitute a major wilderness recreational area enjoyed by thousands of hikers, fishermen, climbers, and sightseers each year. This area is unique in that it provides a truly wilderness experience while still being close to major population centers.

The Forest Service study team was responsible for the sociological portion of the study, and concerned itself primarily with the types and intensity of various recreational activities of visitors to the lakes under study. Also they attempted to assess motivation, degree of satisfaction, and other sociological characteristics of highland lakes visitors. The Cooperative Fishery Research Unit was responsible for gathering and evaluating physical and biological data on the lakes themselves. The data from this dual study are being analyzed and combined for a unified final report.

University of Wisconsin, Stevens Point.—The Wisconsin Cooperative Fishery Research Unit had its first group of students complete thesis projects this year. Abstracts of their research follows:

As part of a study evaluating the effects of removal of woody streamside vegetation on trout streams, monthly drift samples were collected in the Little Plover River during 1972 to determine kinds, density, and seasonal changes in numbers of invertebrates in an up-stream meadow and two downstream brushy areas. Drifting invertebrates were more abundant in the meadow section. The results support a proposal for brush removal as a technique for increasing trout food production in small streams where expected water temperature increases would not be critical.

Effects of Antimycin were observed on non-target benthic macroinvertebrates in Seas Branch Creek, Vernon County, Wis., for 5 months before and 7 months after treatment. Treatment reduced five of eight major taxa,

two increased and one (crayfish) was unaffected. No taxon was extirpated.

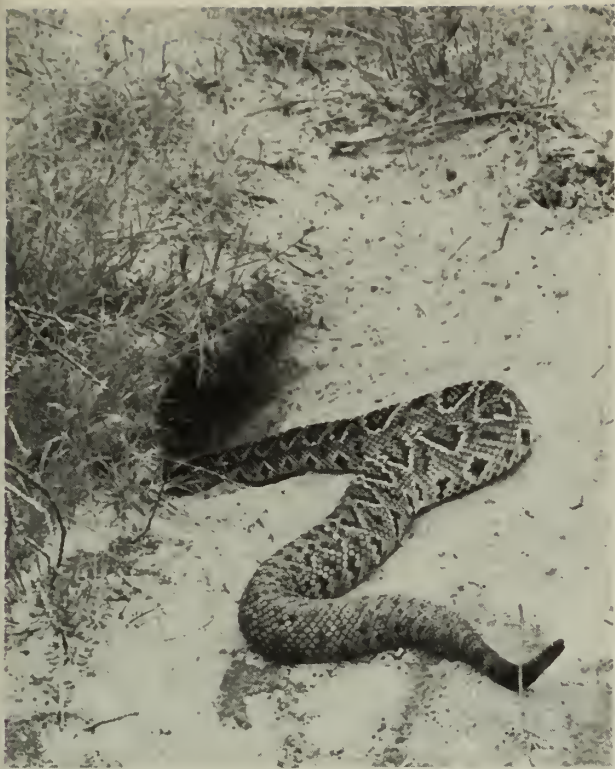
Laboratory and field experiments were conducted to measure effects of sand-gravel mixtures on emergence and survival of brook trout fry. Sand slowed emergence of alevins, and dissolved oxygen concentrations of 0.5 to 7.1 ppm and sand in excess of 20% in spawning gravel reduced fry emergence. Survival was estimated to be 89% from egg deposition to hatching in Lawrence Creek and 70% from hatching to emergence providing a total estimate of survival from egg deposition to emergence of 62%.

Population size, standing crop, movement, food habits, growth rate, age class composition, and total annual mortality were determined for smallmouth bass in the Plover River, Wis. These characteristics plus exploitation and natural mortality rates, and critical size were determined for smallmouth bass in the Red Cedar River, Wis. Calculation of equilibrium yield indicated that weight harvested could be increased by 36% if there were a 9-inch length limit on the fishery and by 44% with a 12-inch limit in the Red Cedar River.

Vulnerability to predation, resistance to high temperature, length-weight relationships, and fecundity were compared for fish (fathead minnow, brook trout, and yellow perch) with and without or with light and heavy infestations of an ectoparasite. Gill lice reduced resistance of brook trout to high temperature. Vulnerability of prey fish to predation was not increased by parasites. Length-weight relationships for parasitized and non-parasitized brook trout and yellow perch were the same. Fecundity of brook trout was not affected by gill lice.

Cooperative Wildlife Research Units

The Program.—The Cooperative Wildlife Research Unit Program began in 1935; today, 39 years later, there are Units at 20 State universities. The program is supported by the co-operating State's Land-Grant University and Game and Fish Department, by the Wildlife Management Institute, and by the U.S. Fish and Wildlife Service. Day-to-day operations are the responsibility of the leader and the assistant leader, who are Service employees holding adjunct faculty positions at the host institutions. Program direction is in the hands of a Coordi-



Eastern diamondback rattlesnake entering tortoise burrow which it uses as a den. (Photo by Dan W. Speake)

nating Committee composed of representatives of the cooperating organizations (with the Institute usually deferring to the Service). Objectives of the program continue to be: (1) conducting research basic to the management of wildlife resources; (2) facilitating the training of wildlife personnel at the graduate level; (3) providing technical assistance to conservation agencies in their wildlife management programs; and (4) promoting education in natural resources through demonstration, lecture, and publication. In recent years research has become the primary operating objective of the Unit program.

The direct contribution of the Units to research and training is at the graduate level. A total of 389 research projects were listed by the Units for the report period which includes academic years 1972-73 and 1973-74. This list may include projects directed by collaborating University staff members. One hundred and twenty of the projects were completed during the reporting period, and 131 theses and disser-

tations were accepted by the universities. (The latter total includes theses written on projects previously reported as complete.) This research effort resulted in 130 publications and 99 papers presented at conferences, meetings, and symposia.

Among the 20 Wildlife Unit universities, 183 students received Unit support in academic year 1972-73 and 212 in 1973-74. Approximately 86% of the 1972-73 Unit-supported graduates obtained employment in wildlife or fishery activities and related fields or returned to college for additional work.

Auburn University, Auburn, Ala.—The common use in the Southeast of gasoline or its fumes to drive rattlesnakes from gopher tortoise burrows during "rattlesnake rodeos" prompted a study of the effect of the substance on inhabitants of the burrows. The introduction of gasoline or its fumes into burrows had no noticeable effect on gopher tortoises. The response of the snakes tested varied with species and individuals. Indigo snakes and pine snakes (becoming rare in the Southeast) were severely affected. Five gassed individuals were driven from the burrows, and four of the five died within 24 days. Some rattlesnakes were killed, while others appeared unaffected. Dosage levels of 2 ounces or more drove two rattlesnakes from the tortoise burrows and killed or inactivated four others.

Despite the apparent lack of immediate harm to the gopher tortoise, the study indicated that the rattlesnake roundups, as they are now conducted, pose an ecological threat that warrants concern. To help protect the beneficial snakes and to provide refuges for other harmless inhabitants of gopher burrows, it is recommended that: (1) the practice of introducing gasoline into the burrows of animals, especially gopher burrows, be banned in National forests, State parks, and on other public lands; (2) some of the protected areas which formerly supported populations of gopher tortoises, indigo snakes, and pine snakes be restocked; and (3) indigo snakes, Florida pine snakes, and black pine snakes be added to the list of protected animals in the States where rattlesnakes are rounded up.

University of Alaska, Fairbanks.—A study of the reactions of semidomesticated reindeer to a simulated pipeline was begun in 1971 on



A herd of reindeer mill about beside a simulated oil pipeline on the Seward Peninsula, Alaska (above). The simulated pipeline was constructed (right) to study responses of reindeer and caribou to man-made obstructions in their migrational path. (Photo above by K. Child, left by P. Lent)



the Seward Peninsula, Alaska. The simulated pipeline, built with 32-inch dredgepipe, extended for 7,500 feet across the Penny River Valley. Two crossings, a gravel ramp and an elevated section of pipe providing an underpass, were constructed as experimental passages across the pipeline for reindeer moving through the valley. Observations of animals and their tracks gave information on the reindeer's reaction to the pipeline, and the deer were herded toward the pipeline six times in different seasons.

Reindeer generally avoided the structure during all seasons. Individuals usually moved parallel to the obstruction until they came to

the end of the pipeline, or they moved away from the pipeline and did not attempt to cross. The animals approached the pipeline to a relatively constant distance of about 164 feet, but

adjacent to the elevated section of pipe (underpass), this distance increased to about 410 feet. This change in distance suggests that the animals reacted to the increased visibility of the elevated pipe. The avoidance of the pipeline by the reindeer and their failure to use the crossings in most seasons may be explained by a combination of several factors. The great visual contrast between the dark silhouette of the pipeline and the white snow background during most months of the year seemed to be important. Reindeer crossed the pipeline under two circumstances: during late winter, when the snow was deep enough to form bridges over the pipeline, and at midsummer, when insect harassment motivated some animals to use the underpass or the ramp. In using snow bridges, reindeer selected sites with a minimum exposure of pipe above snow level and continuous snow up to the pipeline. Such bridges would be unlikely to occur over a pipeline carrying hot oil unless extremely effective insulation was present at certain points. Avoidance reactions of reindeer to the pipeline are not readily altered by short-term experience or habituation. Near the end of the investigation some suggestion of long-term habituation was indicated, however. This may involve individuals who were in repeated contact with the pipeline over several months.

In general, the reactions of the observed reindeer were remarkably similar to those of caribou observed at Prudhoe Bay when the situations were comparable.

University of Arizona, Tucson.—Scaled quail populations vary greatly in Arizona from year to year. This variation may be attributed to rainfall differences, social pressure, and the effects of environmental conditions on the movements of individuals and of populations. A study of the behavioral biology of the species was carried out in Sulphur Springs Valley, Ariz., from June 1972 through June 1974.

Winter flocks dispersed in April as pairs and single males. The transition was influenced by hormonal, nutritional, climatic, and psychological factors. The distribution of birds during the breeding season appeared to be random with respect to vegetation type, but clumping tendencies suggested a preference for calcareous soils and an avoidance of an area supporting Gambel's quail.



The behavior, attitudes, and philosophies of Colorado hunters were ascertained by interviews. (Colorado Wildlife Unit photo)

Following nesting, broods combined with other broods and with miscellaneous adults to form coveys. Although flocking occurred before the development of stresses such as food shortage, low temperatures, and high raptor abundance, it probably functions to minimize the effects of these stresses upon the individual quail. Comparison with other scaled quail populations suggested that the average size of winter flocks was inversely related to winter temperatures.

Sentinel behavior, sharing food, feigning injury in defense of young, and use of alarm calls were examined as possible examples of altruism. The frequency of such behavior patterns was found to correlate directly with the degree of relationship between altruist and recipient and inversely with risk to the altruist. These correlations support the kin selection theory as the evolutionary basis of the behavior patterns.

Colorado State University, Fort Collins.—A structured interview was conducted with 400 Colorado hunters to determine their behavior, attitudes, and philosophies. The sample was selected at random from male Colorado hunters who purchased resident combination (small and big game) licenses in 1971. Techniques used in collecting information included direct questioning, open-ended questioning, and rank-type responses. Present biographic and demographic characteristics such as marital status, occupation, education, and income were compared with



A newly hatched greater sandhill crane chick. The remaining egg in the nest is "pipping." Two eggs per clutch, normally hatching 1 day apart, are usual. (Idaho Wildlife Unit photo)

variables relating to behavior, attitudes, philosophies, and interest in hunting.

The average purchaser of a Colorado combination license was 41 years of age and married. He had been reared on a farm or a ranch, or in a small town, and had hunted as a youth. He had a higher level of education, income, and occupational status than either the average male Colorado citizen or the average resident Colorado hunter without a combination license. He spent more time in pursuit of big game and harvested more big game than the average Colorado hunter in 1971. One-third of the combination license purchasers were members of sportsmen's clubs and three-fourths read hunting and fishing magazines regularly. Most also fished and camped.

Big game was the most popular type of game hunted in Colorado. The most favored area for

hunting big game was public land; small game and waterfowl were hunted mostly on private land. Initial interest in hunting was brought about by love of the outdoors, the influence of friends or relatives (mostly fathers), proximity to hunting areas, and interest in guns. Major reasons given for hunting were love of the outdoors, companionship, challenge of the chase, and the need for outdoor recreation. Lack of leisure time was the major factor limiting participation in hunting, and stimulation by fellow sportsmen was the principal factor enhancing interest in hunting. The major reasons for taking children hunting were to develop their knowledge and appreciation of the outdoors and of such qualities as sportsmanship and responsibility.

Major concerns of those interviewed were big game hunting seasons, the anti-hunting movement, and the problem of undesirable hunters. Results indicated that recreational benefits of hunting can be increased through hunter safety programs, information and educational programs, management programs aimed at fathers and sons, and improving undesirable behavior by hunters.

University of Idaho, Moscow.—Greater sandhill cranes nest mostly from northwestern Utah along the Idaho-Wyoming border to southwestern Montana. They have increased substantially since 1944 when 188 to 250 pairs were believed to exist in this region. During a study from 1969 to 1971, the fall-winter population in the northern Rocky Mountain region was judged to be 10,000 to 15,000. It is estimated that 250 pairs nest at Grays Lake, Idaho, the highest reported density in North America. Nesting was from late April through early July and incubation averaged 30.2 days. Mean clutch size was 1.94 (range, 1–3) eggs; mean brood sizes were 1.77 at hatching and 1.35 at fledging. Nest success was 78%. Fall flocks contained 16 juveniles per 100 adults, indicating a low recruitment rate. Pairs maintained mutually exclusive territories and both sexes assisted in territorial defense. The young fly at an age of 67 to 75 days. Families vacate territories to join postbreeding flocks which gather annually in the fall at premigration staging areas in southeastern Idaho and western Wyoming. More than 1,700 sightings of 251 cranes, color-marked on breeding grounds in four States,

demonstrate that cranes migrate mainly in September and early October through eastern Utah and western Colorado to the San Luis Valley, Colo., their only stop during migration. In November most individuals move to wintering areas in western New Mexico, southeastern Arizona, and northern Mexico. Spring migration follows the fall migration in reverse, and the cranes return in April to the same territory used in previous years.

Iowa State University, Ames.—A study of patterns of recreational use and characteristics of users was conducted on a 74-mile stretch of the Upper Iowa River in 1972–73. Canoeing was the most prevalent recreational use, followed by camping and fishing. Canoeists and campers were chiefly from Iowa (87%) and traveled an average of 87 miles to the River; fishermen (94% from Iowa) averaged 43 miles of travel to the River. Most canoeing and camping took place on weekends with a peak on National holidays, and both activities increased from 1972 to 1973. Most campers used tents and over 42% of the camping was on private land. Users desired more facilities such as campsites, tables, and toilets, and 83% were willing to pay a user fee. Users were against commercial developments along the River. “Scenic beauty,” “free-flowing, clear water,” “escape from the crowded city,” and “communing with nature” were aspects of a river recreation experience rated highest by users. More user facilities are needed at high-use access areas to lessen environmental degradation by recreationists and at less used areas to spread out recreational use of the River.

Analysis of aerial photographs and annual crop reports for 27 counties in north-central Iowa has shown a major change in land use, although the percentage of land used for crops, pasture, and Federal land retirement has remained at 89% since 1939. From 1939 to 1972, the proportion of land in pasture, small grains, and hay decreased from 55 to 17% while that of corn and soybeans increased from 32 to 58%. Since 1939 drainage ditches increased 44%, resulting in a loss of wetlands, and undisturbed grassland and fencerow areas decreased by 71 and 31%, eliminating pheasant habitat. Total nesting cover for pheasants decreased from 62 to 35%, but high-production nesting cover decreased from 30 to 7%. These changes in land



“Scenic beauty” and “communing with nature” were the most popular reasons for using the Upper Iowa River for recreation. (Photo by A. O. Haugen)

use have resulted in much reduced pheasant populations in north-central Iowa.

Louisiana State University, Baton Rouge.—Species of coastal marsh vegetation varied widely in their response to crude oil applied under controlled conditions. The growth of one emergent species important to wildlife was actually enhanced at higher experimental oil concentrations, providing the water level was maintained above the marsh floor.

Attempts to develop sexing and aging techniques from external characters of common snipe had limited success. Shaft length of the outer rectrix (tail feather) was the practicable character for sexing, and it was accurate in only 76.1% of the birds examined. Age appeared to be reflected in leg color, but the technique could not be reliably tested on the wintering grounds in Louisiana.

Evaluation of an experimental harvest of alligators was undertaken in cooperation with the Louisiana Wild Life and Fisheries Commission. Results indicated that a controlled harvest of surplus alligators in one part of their range was practical and feasible without jeopardizing populations in other parts of the range.

University of Maine, Orono.—Analysis of 2,665 bandings and 429 recoveries reveal that eiders are largely coastal migrants. Adult females from summer banding areas in Maine,



The effect of harvest on alligator populations is being studied in Louisiana. (Louisiana Wildlife Unit photo)

Quebec, Nova Scotia, and New Brunswick winter mostly along the coast of Maine and Massachusetts. By contrast, birds of the year from Maine appear to winter in southern Nova Scotia as well as in Maine and Massachusetts. Migrational homing of adult hens to specific breeding areas may approach 100%. The average annual mortality for adult females from Maine and Quebec are 24 and 22%, respectively. The pre-hunting season population was estimated to be 325,000.

Marshes were stocked with three species of hole-nesting waterfowl by moving hens and their newly hatched young in nest boxes. Survival for these released broods averaged 42% for wood ducks, 50% for goldeneyes, and 40% for hooded mergansers. Of 87 female wood ducks released as day-old ducklings, 9.2% were known to nest on the release marshes the next year. Fifty percent of 30 adult wood ducks that were moved with their broods to new areas returned to their original test marshes in following years.

A 3-year survey of breeding ospreys has been completed on the Maine coast. The number of young per nesting attempt increased each year, and more ospreys appeared to be nesting in 1973 than previously. Of 73 active osprey nests observed in May 1973, 45 contained 82 young

in July. Thus, about 62% of the clutches were successful and there were 1.12 young per nesting attempt on the area as a whole, but this figure varied considerably between localities. Successful active nests were 63% of the total and contained an average of 2.0 young in Penobscot Bay, 75% and 1.7 young on Sheepscot River, 46% and 1.2 young at Mount Desert Island, and 58% and 2.4 young at Muscongus Bay.

University of Massachusetts, Amherst.—Information on the range, movement, and habitat preferences of the fisher in the White Mountain National Forest is being obtained by radio tagging. Fisher are extremely active, even during daylight hours, and travel many miles during their daily hunting. Deer yards in spruce-bogs are much used during the winter and fisher feed on deer dying from malnutrition or predation by other carnivores. Fisher shift their activities to mixed hardwoods at higher elevations during the spring. When captured some fisher, especially males, have porcupine quills embedded in their flesh. Nursing females are excessively active and spend little time actually caring for the young, returning to the den only long enough to nurse.

An intensive study of the giant Canada goose was completed in 1973. Nest attentiveness and temperature of the air cell in the egg was monitored electronically during the 1968–71 nesting seasons. Snow cover and strife between nesting geese play a significant role in site selections and nest establishment. The same site was seldom used by the same female in successive years, but surviving birds did nest in the same general marsh area each season and showed a preference for the same type of nest site. Contrary to earlier evidence, incubation does not begin abruptly but the females become progressively more attentive as more eggs are deposited. The giant Canada is a tenacious incubator spending 98.5% of the time on the nest. Females left the nest 1.36 times a day for an average period of 14.7 minutes, usually between 3:00 to 6:00 a.m. and 3:00 to 9:00 p.m.

University of Missouri, Columbia.—A study of the effects of dietary dieldrin on fertility and fecundity of captive raccoons was carried out during two breeding seasons. One of two groups, each consisting of 10 yearling males, 10 yearling females, and 10 adult females, was given a



The fisher, a valuable furbearer found in most of forested States on the Canadian boundary, is being radio-tracked in northern New Hampshire. Note the transmitter collar (top) and the obvious speed of the animal (bottom photos taken at 1/250 second). (Photos by G. M. Kelley)

control diet; the other received a diet treated with 2 ppm dieldrin. Reproduction was significantly lessened in at least some groups of treated females compared with controls in the following ways: delayed onset of estrus, shortened estrous periods, and reduced receptivity to males. Dietary dieldrin may have inhibited spermatogenesis in males and reduced viability of sperm. Eight dieldrin-treated females died, probably of dieldrin poisoning. These experiments showed clearly that dieldrin fed at 2 ppm in diet reduced productivity in raccoons, and the results constitute one of the clearest sets of evidence available that chlorinated hydrocarbons have this effect on a mammal.

Wild young-of-the-year cottontail rabbits, confined in 1-acre pens, were exposed to annual ground applications of 0.5 and 2.0 pounds per acre of granular dieldrin. Reproductive data from rabbits in treated pens were compared with control groups during six breeding seasons. Residue levels in brain, liver, and muscle of rabbits from the two treatment levels were significantly higher than those of control animals. Lethal accumulations of dieldrin were found in brains of three cottontails. Fewest breeding animals were recovered from pens with highest treatment levels. No differences in reproductive performance of males or females were found among animals in treated and untreated pens, based on testis size, presence of spermatozoa, onset and synchrony of breeding, ovulation rates, and embryonic litter sizes.

University of Montana, Missoula.—The ecology of polar bears was studied during summer and fall for 3 years on North Twin Island in James Bay, Canada. Ground observations showed that both lone bears and families spent most of their time resting while on the Island. Feeding was seldom observed; when it was, the main foods were crowberries and geese. Aerial censuses indicated that the polar bear population on the Island increased gradually during the ice-free season (July to November). At least 40 bears were present during 1970 and at least 22 during 1971. Observation during 1970 of 17 bears, marked by the Canadian Wildlife Service, indicated that, once they arrived there, bears remained on the Island through the ice-free season. Failure to observe the marked bears in 1971 suggested that a discrete population does not visit North Twin Island every

year. North Twin Island apparently recruits from a population of polar bears that range over the islands of the James Bay area in summer and fall.

Interspecific and intraspecific variation was studied in 547 westslope cutthroat trout, yellowstone cutthroat trout, and rainbow trout taken from 25 locations in Montana and Yellowstone National Park. The three kinds of trout were distinguished on the basis of the frequencies of discrete serum proteins and their overall phenotypes. Populations of westslope cutthroat trout were biochemically more closely related to those of rainbow trout than to those of Yellowstone cutthroat trout, even though both cutthroats are presently classified as one species. The stocking of exotic species of trout is almost certainly the greatest immediate threat to native populations of westslope cutthroat trout.

Cornell University, Ithaca, N.Y.—A field survey of 28 townships drawn from 100 townships examined in New York State in 1963 revealed that, by 1973, over 3.4 million acres of private land, mostly well-suited to outdoor recreation, had been added to the 5.5 million acres posted against trespass in 1963. Of the State's 30 million total acres, 42% of New York's private lands are now posted. If the 1963-73 trend continues, all private acreages in the State will have been posted by 1993. The proportion of posting parallels population pressure and is highest, 55%, in southeastern New York. West-central New York is 51% posted, and northern New York is 25% posted, the lowest proportion.

Landowners who posted their land were asked to indicate their reasons for posting. Fifty-five percent of them reported bad experiences with recreationists: 56% of these were with hunters, 26% with snowmobile operators, 7% with fishermen, and 11% with other recreationists. Another 20% of the landowners reported the bad experiences of a friend or neighbor as the reason for posting. Of this group, 62% cited hunters; 24%, snowmobile operators; 6%, fishermen, and 11%, others. A third group of landowners (37%) cited the recreationists' reputation for damaging property as a reason for posting. Of these, 44% mentioned hunters; 33%, snowmobile operators; 7%, fishermen; and 10%, others.



Wood ducks were banded in Ohio to study their roosting habits. (Photo by Richard D. Curnow)

Ohio State University, Columbus.—Fall roosting-flight counts have been used as an index to wood duck abundance. The extent of interroost movements and their effect on the reliability of this index was studied in north-eastern Ohio where roost flights that included marked wood ducks were counted on 129 evenings in fall 1971 and 1972. It was learned that mist-netting on small swamps (less than 5 acres) resulted in the capture of nine times as many wood ducks per man-hour of effort as drive-trapping. The extent of interroost movement could not be ascertained on an undisturbed marsh, but drought, flooding, and activities related to the various methods of trapping frequently caused roost abandonment. However, the results of this study did show that roosting flight counts did not provide a reliable index to wood duck abundance in the area studied.

Gang broods (combinations of several broods) of giant Canada geese were studied on a northwestern Ohio goose production area. Observations were aided by color marking 56 broods (285 goslings) and 23 adults. Two types of gang broods were identified. One type formed early in the brood-rearing period (goslings less than 2 weeks old) and was accompanied by only one pair of adults. The second type was formed later, when several families formed large groups (as many as 75) and moved, fed, and loafed together. Gang broods had survival value, particularly for the wandering individual gosling. Factors contributing to gang brood formation included:

- (1) dominance of one pair of adults and their brood over another pair and brood,
- (2) broods in close proximity, and
- (3) the individual quality of each pair of adults as parents.

Oklahoma State University, Stillwater.—A study was conducted to analyze the feasibility of employing the multiple-use concept to provide increased recreational opportunities on public school sections of lands. Objectives were to determine: (1) acreage of vegetative cover types on public school lands in Payne County, (2) relative abundance of wildlife in the cover types, (3) attitudes of lessees toward wildlife-oriented recreation on their leases, and (4) hunters' and fishermen's opinions concerning the quality of their outdoor recreation experiences on public school lands. Acreages of 13 cover types were computed from cover maps for all school lands. Surveys that measured animal abundance and species diversity were made on nine 1-square-mile tracts selected at random. Questionnaires were completed by both landholders and sportsmen.

Native pasture, cultivated land, and post oak-blackjack were the most prevalent cover types. Uneven distribution of vegetation permitted a wide variety of habitat conditions. Fifty species (1,176 individuals) of wildlife were observed, indicating a high diversity. Bobwhite quail, coyotes, fox squirrels, and cottontail rabbits were common.

Seventy percent, or 14,141 acres, of school land was open to at least one type of recreation when stipulations of the lessees were met. Fishing was potentially open on 63% of the farm ponds. Although 58% of the responding lessees posted their school land, 60% of these lessees would allow at least one type of recreation. The lessees' attitudes and opinions were influenced largely by their past favorable or unfavorable experiences with sportsmen, and whether they anticipated problems in the future. School lands were utilized by 32% of the responding hunters and 44% of the fishermen. Hunting success was slightly higher on school lands than elsewhere, but the difference was not statistically significant.

Oregon State University, Corvallis.—Since 1950, when three male and two female (1 kid) mountain goats were introduced in the Wal-lowa Mountains of northeastern Oregon, population increases have been slow. The age



Mountain goats, introduced in the Wallowa Mountains of northeastern Oregon, often bed on residual snow banks in summer.

composition of the herd of 29 goats at the end of the 1973 kidding period indicated that three kids had been recruited each year during 1971-73. A minimum of 10 breeding-age females were present, and the six kids produced in 1972 and 1973 were by six different females. Data gathered during the study indicated that the most likely cause of low productivity in the goat populations was lack of suitable winter range. Summer range was ample, but the herd of goats restricted themselves to a small segment of their range in winter and over-utilized the forage. Nutritional stress apparently resulted and may have produced the prenatal or early postnatal mortality.

Ninety-three northern sea otters were liberated in the southern coast of Oregon in 1970 and 1971. In 1971, Oregon Unit personnel began a 2-year study of the sea otters to ascertain the short-term success of the transplants. Throughout the study period, no more than 23 otters were observed on any census day. Eight otters are known to have died, seven within 1 week

of release. The fate of the unaccountable animals is not known, but emigration seems a likely possibility. The information gained by the study suggests that the attempt to reestablish the sea otter in the State at least has had short-term success. Thus, a reproducing colony, estimated to number 30 to 35 sea otters, is at present reestablished where otters have been absent for nearly 100 years.

Pennsylvania State University, University Park.—The increasing number of hunters and the large kill of black bears in Pennsylvania have prompted studies of the species to obtain information for more detailed management. Field studies have centered in Pike County, northwestern Pennsylvania, but data from bears killed by hunters are collected from throughout the State.

The average ages of 119 male and 29 female black bears harvested in the State in 1971 and 1972 were 2.9 and 3.9 years, respectively. In 1973, 299 bears killed by hunters averaged 2.6 years of age. This age structure is characteristic

of a declining population. However, field reports and harvest figures over a period of years do not indicate a decline of the magnitude suggested by the age structure, so the population sample for aging may have been biased.

In the Pike County study area, mortality rates of adult-sized bears were 68% for males and 71% for females. Observations of 16 family groups indicated an average production of 2.4 cubs per female. Although a female gives birth to cubs every 2 years, different females from a population should produce a similar number of cubs each year. However, a sample of 70 bears, whose years of birth were determined from estimated ages, gave evidence of synchrony in cub production; 43 were born in one set of alternate (even-numbered) years and 27 were born in the (odd-numbered) years between. This difference was statistically significant.

Eighty-nine percent of the observations of marked male bears were less than 6.2 miles from their calculated centers of activity; the comparable figure for females was 1.9 miles.

South Dakota State University, Brookings.—Between 1968 and 1970, 222 giant Canada geese were released on small lakes and stock ponds in Jackson County and parts of Haakon and Pennington counties, western South Dakota, to reestablish a breeding population. The success of the restoration, especially yearly production, was evaluated in 1970–71. Nests were built on islands, peninsulas, shores, small dams, and artificial structures. Eighty-five percent of 82 nests were in ungrazed sites but almost all nests were in relatively bare areas that afforded maximum visibility for the nesting geese. Clutch size ranged from two to nine eggs and averaged 4.9 in 1970 and 5.5 in 1971. Eggs hatched in 78% of the nests; 55% of the unsuccessful nests were destroyed by predators. During the 2 years, 295 goslings were produced and 263 (89%) were raised to flight stage. Nearly all of the gosling mortality occurred during the 2 weeks following hatching, when broods moved an average of 2.7 miles to the rearing-molting area. Seventy percent of the geese were recaptured within 5 miles of the original release or rearing site. Thus, high nest success, low mortality of goslings, and homing to the release area contributed to the restoration of a self-sustaining population.

South Dakota voted to discontinue hunting

mourning doves in 1972. Interviews with voters indicated that opposition to mourning dove hunting in South Dakota was not associated with general opposition to hunting, hunters, and game management practices, but was primarily based upon the incorrect belief that mourning doves are not game birds in most of the United States.

Utah State University, Logan.—About 70 million acres in western North America is covered with pinyon-juniper (P-J) trees, and 54% of Utah's mule deer winter range consists of this woodland. Thus, conversion of P-J to a grass-dominated community for grazing may have a considerable effect on deer range. Based on 10,000 observations of individual deer on three sites during a 3-year period, some conclusions of a study of mule deer-converted P-J relationships were: (1) no increase in deer numbers was correlated with P-J conversion, (2) increasing deer use was concentrated on



A red sea urchin. Sea urchins, both purple and red, are important foods of the sea otters transplanted in Oregon's coastal waters. (Photo by Dale Swanson)

natural P-J, (3) most deer use on P-J conversions occurred in March and April, (4) P-J conversions contributed 25 to 30% of the deer forage but made up over 50% of the land area, (5) deer use was greatest on north exposures in the natural P-J and on south exposures on conversions, (6) no edge effect existed in a mile-wide zone of natural P-J adjoining converted P-J, and (7) P-J conversions decreased mountain-mahogany, Gambel oak, and pinyon densities but increased juniper and sagebrush densities.

For deer management, it is recommended that P-J conversions should be: (1) less than 0.4 mile wide and no more than 20% of the winter range; (2) converted by single chaining only; (3) confined to small valleys and gentle slopes, largely on south and west exposures; and (4) grazed in a spring-fall rotation by cattle.

Virginia Polytechnic Institute and State University, Blacksburg.—Free-running dogs are supposedly a serious threat to deer and other wildlife in various ways, but there are few scientific facts to support or refute this viewpoint. A study was conducted at the Radford Army Ammunition Plant, Dublin, Va., to learn if dog-chasing of pregnant white-tailed deer reduced the survival of their fawns and if home ranges were changed as a result of dogs pursuing deer. During the first phase of the study, 22 April–3 June 1972, trained deer hounds were allowed to chase deer in one-half of the study area; the other half was reserved as a control area. During the second phase, 21 October 1972–26 May 1973, hounds and other breeds of dogs chased deer on the entire fenced area of 2,040 acres. No significant difference was found between the survival of fawns from does chased by dogs and from does that were not chased. No permanent home range changes were noted as a result of dog-chasing, but some temporary ones were made. Most of the does making the temporary changes returned to their normal home ranges in a few days.

Another study at the Radford Ammunition Plant was designed to ascertain the effect of orphaning white-tailed deer fawns in autumn. Data collected on 21 fawns separated from their mothers in fall 1973 and 18 unorphaned fawns indicated that orphaning had no influence on their survival. All of the fawns were alive at the conclusion of the study in March 1974.



A white-tailed deer fawn. Fawns orphaned (experimentally separated from their mothers) in the fall of the year survived through the following winter. (Photo by Robert Downing)

Orphaned twins remained together, and orphans without siblings sought the company of other deer, either family groups, other orphans, or adult bucks. Mean shifts in centers of activity were 764 feet for orphans without siblings and 560 feet for controls. The data are interpreted to indicate that orphaning causes a conflict between the need to remain in familiar territory and a desire to associate with other deer.

University of Wisconsin, Madison.—Excessive eggshell cracking and embryonic mortality have continued among herring gulls in the Green Bay region. In 1973, 66 of 102 nests had one or more eggs with cracks or breaks in the shell, and 24% of the eggs had dead embryos. This degree of mortality in the heavily polluted population is slightly less than that recorded 10 years ago, and the decrease seems to have continued in 1974.

At least 100 pairs of bald eagles nest in Wisconsin each year, but not all pairs produce young because of variable food supplies, disturbance, and other factors. In 31 days of observation at 6 active nests in 1974, adult eagles brought in 120 food items. At least 98% of these items were fish, mostly northern pike and suckers. The fish averaged 2 inches in length. Preliminary data on eagle activity suggest that only one or two lakes may be intensively hunted by each pair of eagles.

PUBLICATIONS

Listed below are titles of articles published from 1 January 1973 to 30 June 1974 and a few papers published in 1972 that were not listed in the previous annual report. The articles were published in technical and scientific journals, magazines, proceedings, transactions, and other media.

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APPENDIX

Directory of Research Facilities and Personnel

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Division of Cultural Methods Research

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Division of Population Ecology Research

Dr. James A. McCann, Chief

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Colonial nesting seabirds, predominately common and thick-billed murres and black-legged kittiwakes, on the north shore of Bristol Bay, Alaska. (Photo by James C. Bartonek)



Rock Creek, Wells County, Ind., before (above) and after (below) channelization. The objectives of the National Stream Alterations Research Program are to investigate the effects of stream channelization on fish and wildlife and to provide technical advice and recommendations for mitigating those effects. As an example, the Service recommended alternate bank clearing for the Rock Creek project. (Photos by Jay F. Watson)

